COMMERCIAL GARDENING

EDITED BY
JOHN WEATHERS

Commercial Gardening

MARKET CHRYSANTHEMUMS

1. Le Peyron. 2. Freda Bedford. 3. Elsie Fulton. 4. Mrs. F. MacNeice

(Half natural size)

COMMERCIAL GARDENING

A PRACTICAL & SCIENTIFIC TREATISE FOR MARKET GARDENERS · MARKET GROWERS · FRUIT FLOWER & VEGETABLE GROWERS · NURSERYMEN ETC.

By Many Practical Specialists
under the Editorship of

JOHN WEATHERS

Author of "A Practical Guide to Garden Plants"
"French Market Gardening" "The Bulb Book" &c.

In Four Volumes: Fully Illustrated

VOLUME I

THE GRESHAM PUBLISHING COMPANY
34–35 Southampton Street Strand London
1913

PREFACE

The very title of this work at once distinguishes it from all other treatises on Horticulture, and at the same time strikes a note indicating its predominant features. The work is "commercial" in every sense of the term, because it deals with gardening from the point of view of the man who grows plants not so much for pleasure as for profit. It is also "gardening" in the best sense of the word, as the cultural methods of the best market growers are detailed. *Commercial Gardening*, indeed, is intended as a work not only for the bookshelves, but for the hands of all those who are engaged, or intend to become engaged, in Horticulture for Profit, and who are desirous of growing those crops of fruits, flowers, or vegetables likely to yield the most remunerative results.

In considering gardening from what may be called a pounds, shillings, and pence point of view, it is essential to take note chiefly of those crops that can be grown in the open air or under glass, and are likely to yield a profit, large or small, upon their cultivation. It does not at all follow that what may be justly regarded as the loveliest and most charming flowers, the most decorative plants, or the finest-flavoured fruits or vegetables, are necessarily those that will yield the handsomest profits when cultivated on a large scale. Unfortunately the reverse is often the case, and enormous numbers of various plants are grown, not because they happen to be the very finest representatives of their class, but simply because they find a more ready sale in the markets than their choicer brethren. This is easily explained on the ground that those who grow produce for sale, and those who buy it, belong to quite different classes of the community. The market buyer usually is not a trained horticulturist, and he will only invest in produce that has already made a name for itself, and is therefore not likely to remain long on his hands. If he ventures to invest in produce which he has never seen before, or knows but little about, he finds that when he recommends it to his customers they leave

it severely alone—evidently under the impression that he is trying to push unduly the sale of what he considers to be a useless drug on the market. Many excellent plants have met this fate, and it has taken years before others have become sufficiently well-known to florists, greengrocers, and street sellers to make their cultivation at all profitable. Sometimes, however, a new kind or variety will jump into popular favour at once, and the commercial gardener, who is regularly in touch with the markets and is being constantly influenced by their atmosphere and traditions, proceeds at once to propagate and cultivate the new favourite in sufficiently large quantities to meet the demand. In this way some of the older favourites are gradually displaced by the newer ones, and it is only when one comes to compare the kinds or varieties of plants or flowers that were sold in quantities twenty, thirty, or fifty years ago with those sold at the present day, that one realizes what enormous changes have taken place.

Not only have new races superseded old ones, but the cultural methods of commercial gardeners have also undergone remarkable changes. Cleaner and more economic methods of cultivation also prevail to-day, and gardeners who have to make a living out of the growth of plants have in many cases come to recognize the vast importance of the scientific aspects of their calling. In these days the grower who would erect glasshouses with small panes of glass and an enormous quantity of timber would be regarded as insane. The importance of light and fresh air is now so well understood, that the main object in view is to secure as much of each, especially during the winter months, as is possible.

The market gardener has perhaps more to learn in this respect than the market grower. In many instances he practises the old and erroneous farming system of cramming and crowding his fruit trees and bushes together in such a way that in a few years they become a mass of diseased and distorted vegetation, yielding very poor, if any, profit. It is one of the most difficult things to make some of the old school of market gardeners and farmers realize that the great bulk of the dry weight of any plant—fruit, flower, or vegetable—is obtained from the carbon of the atmosphere under the influence of sunlight. They simply will not believe it because they cannot see it. It is ever present to the minds of such that to give any plant a fair amount of space and air and light, according to its nature, would be "wasting ground", as they term it. The natural corollary to this lack of knowledge is the thought that the greater the number of plants put into a given area of ground, the larger and better

the crops likely to be got out of it—one of the most pernicious and dangerous doctrines for any commercial gardener to play with.

In this work on Commercial Gardening the best and cleanest methods of cultivation are those recommended, simply because they happen to be the most economical. But no false economy is preached, and it may be cheaper, even for the man with a small capital, to make a fair start by thoroughly cultivating his ground to a depth of 3 ft., at a cost of £8 to £12 per ac., than to fritter away his substance for a lifetime and never go deeper than six inches or a foot from the surface. The cultivator who is now foolish enough to think that the methods employed by his ancestors in the old non-competitive days are quite good enough for him, is making a sad mistake in these speedy days of keen competition. The modern grower is affected by the changes brought about by science and fashion, and he must adjust his methods and vary his crops according to prevailing circumstances. Perhaps it only remains to be said that the information given in this work has been supplied by men most of whom are, or have been, actually engaged in growing crops of various kinds for profit, and are regarded as skilful cultivators and good business men. The Editor takes this opportunity of thanking them for their kind assistance, and in doing so would also like to express his indebtedness to many other commercial gardeners—who prefer to handle the spade rather than the pen—for many hints and much information given in regard to various matters.

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VOLUME I

SECTION I

General Aspects of Commercial Gardening

During the past fifty or sixty years horticulture has sprung into a prominent position as one of the leading industries of the United Kingdom. Horticulture, unlike its twin sister agriculture, is not represented in Parliament, and the only legislative notice taken of it has been to make its disciples pay rates and taxes on their skill and industry. When we have a Minister of Horticulture, as the French and Belgians have, then perhaps the horticultural trade will receive as much consideration as agriculture does in connection with the rating of the land, and more importance will be attached to it as a national industry.

Horticulture, as distinct from agriculture, has to deal with the cultivation of all kinds of plants and flowers, fruits and vegetables, both in the open air and under glass. Besides our native hardy fruits, flowers, and vegetables, the horticulturist also has to grow exotics from all parts of the world—from the tropics, subtropics, and temperate regions, from the mountains and valleys, and from all kinds of soils and situations. To bring these to perfection necessitates considerable skill, besides great expense. The horticulturist has found out that the rather antediluvian methods of the agriculturist would be of little use to him. He must mix his soils and composts in various ways to suit particular crops, and he must regulate the temperature by means of glasshouses and frames and hot-water apparatus if he is to succeed. This necessitates outlay in other directions, and the timber, glass, and iron trades benefit by his enterprise, as well as many others that supply horticultural sundries. Indeed it is almost impossible to describe the intricate details of horticultural practice, and it must suffice to say that they are such as would astonish the average agriculturist. Although both farmer and gardener have to practise the same principles of cultivation for outdoor crops, the gardener, even with these, will devote far more attention to detail, and will spend an amount of money every year in cultivation that the farmer would consider exorbitant or extravagant. The farmer leaves

a good deal to nature; but the gardener, and especially the commercial gardener, cannot afford to leave his various crops altogether exposed to the mercies of a somewhat fickle climate. He prepares his soil to a greater depth, and feeds it more richly with manure than does the farmer; and he also pays greater attention to cultural details. In addition, he must gather his crops, not for cattle, but for human consumption, just when they are ready, and he must pack them in such a way that they will readily attract buyers in the markets. At one time, indeed, the market gardener was little better than a farmer in his cultural and business methods, and he sent produce to market in a very slipshod manner. The stress of competition at home and the importations from abroad, however, have completely changed the methods of the modern market grower. He has found out by experience that the finer, better, and cleaner his produce, and the better it is packed or displayed, the higher the prices and the quicker the sales. He has learnt much in these respects from the way produce from the Colonies and from the Continent is placed on the markets, and he realizes that good stuff badly displayed will often fetch miserably low prices.

This work on commercial gardening deals principally with those classes of plants that are grown in large quantities either in the open air or under glass for sale in the London and provincial markets, and also those that are grown by nurserymen and hardy-plantsmen in fairly large numbers to meet the demands of their customers who do not patronize the markets. There are, indeed, so many ramifications of the horticultural trade, each intimately associated with the other, and dependent on each other, that it may be well to say a few words about each to show how one is linked up with the other.

The Seed Trade.—This branch of commercial gardening has assumed immense proportions of late years. In various parts of the kingdom firms have established trial grounds where their seeds are not only saved, but where new varieties likely to have a ready sale are also tested and proved before being placed upon the market. This work necessitates great care and cultural skill; and expensive machinery, driven by steam or the more modern electricity, is used to cleanse the seeds from impurities of every sort. Large warehouses have to be built to accommodate the stocks, not only of home-saved seed, but also of that imported from sunnier climes than our own. To give some idea as to the trade done in seeds it is only necessary to state that one firm alone sells each year about 50,000 bus. of culinary Peas; 51,000 bus. of root-crop seeds; 6500 bus. of Beans; 41 tons of seeds of the various Cabbage crops; 1300 bus. of Radish seeds; 25 tons of Beet seed; 1400 bus. of Spinach seed; 10 tons of Onion seed; 17 tons of Carrot seed; 220 bus. of Parsley seed; 10 tons of Parsnip seed; 15 tons of Sweet Pea seed; 14 tons of Nasturtium (Tropæolum) seed; and 3 tons of Mignonette seed. Seeds of annuals, biennials, and perennials of all kinds are sold in large quantities year after year, and are retailed in packets costing from 1*d.* upwards.

The Bulb Trade.—Although a large proportion of the bulb trade is undoubtedly Continental, there has been a magnificent effort on the part of British and Irish growers to produce large quantities at home. While such bulbs as Hyacinths and Tulips and Daffodils have been for generations a staple industry of the Dutch growers, signs are not wanting that equally good bulbs can be grown in several places in the United Kingdom. With the exception perhaps of Hyacinths, other bulbs of a hardy nature might be grown more extensively. In the Channel Islands and the Scilly Islands, in parts of Ireland and England, Tulip and Daffodil bulbs are now grown on a large scale and of the finest quality, but the methods of British growers in calling attention to their stocks are far inferior to those adopted by the Dutch. The latter band themselves together for mutual trade benefit, and make a point of encouraging visits to their bulb farms every season. The trade practically commences in the spring, when Dutch growers book orders from the visiting growers, and deliver the goods as early in autumn as possible. During the summer months —from May to August—their travellers invade the British Islands and America, and push the bulb trade so well that they take home fine fat orders for early autumn delivery. From September to December the trade is brisk amongst retailers, while the market grower has already boxed his bulbs of Tulips, Daffodils, Hyacinths, Crocuses, Snowdrops, &c., to secure an early Christmas and Easter trade.

Tulips, Daffodils, Hyacinths, and Crocuses are abundant from Christmas to Easter; while *Lilium longiflorum* is now practically in season throughout the year. Gladioli of the Colvillei and nanus sections are also useful for spring work, while the Brenchleyensis, Childsi, and Nanceianus sections come in for late summer or early autumn work.

Apart from bulbs proper, such tuberous-rooted plants as Arum Lilies are in great request from Christmas to Easter and Whitsuntide, the chief trade being done in the blooms or spathes.

Ixias, Freesias, Snowdrops, German, Spanish, and English Irises, Tuberoses, Montbretias, Solomon's Seal, Crown Imperials, Herbaceous Pæonies, Eucharis, Dahlias, &c., are amongst other bulbous and tuberous plants that find a ready sale throughout the year at their own particular season, for the cut-flower trade. Each group is dealt with in its proper place in Vol. II of this work.

Amongst retail nurserymen and bulb merchants other bulbous and tuberous plants dealt in, as well as those mentioned, are Begonias, Dicentras, Gloxinias, Hippeastrum, Leucojum, Chionodoxa, Scilla, Alstrœmeria, Brodiæa, Brevoortia, Galtonia, Hæmanthus, Ranunculus, Winter Aconite (Eranthis), Calochortus, Camassia, Colchicum, Erythronium or Dog's Tooth Violet, Eremurus, Incarvillea, Ixiolirion, Lycoris, Milla or Triteleia, Muscari or Grape Hyacinth, Ornithogalum or Star of Bethlehem, and many others, including the Water Lilies or Nymphæas which have become popular of late years. Most of these are practically hardy, and the trade in them is confined to nurserymen and hardy-plantsmen who

deal with the owners of private establishments. Each genus is dealt with amongst the "Plants and Flowers" in Vol. II.

The Hardy-plant Trade.—Of late years the trade in hardy plants has assumed almost gigantic proportions. Not only are large quantities of hardy herbaceous perennials actually sent to the various markets for sale packed in various ways and sold as "roots", but a still larger trade is done through the post, by means of exhibitions, and by advertising in the papers. Owing to the cost of erecting glasshouses, the cost of fuel, and other items of expense many private people have discarded glass altogether, or the newer generation has not taken a fancy to it owing to the trouble and expense. To such, the hardy herbaceous perennials, and hardy annuals and biennials, naturally appeal with great force. There is no need to have glasshouses of any description to grow these plants, and even a cold frame can be dispensed with; and yet a magnificent display may be secured by a judicious selection of plants that will flourish in the open air in most parts of the kingdom without any artificial protection. This being the case, it is not to be wondered at that a large trade has sprung up in these plants, and something like three or four thousand different species are now dealt in by various growers, some of whom hold valuable stocks of the best-selling kinds, while others cater for a select group of plant connoisseurs and botanical establishments.

The grower of hardy plants, as a rule, does not go to market, and his methods of business are quite different from those of the market grower. He relies very largely for his sales upon his catalogues (which are often works of art), upon exhibitions in all parts of the kingdom, and upon judicious advertising, very much in the same way as the seedsman and bulb merchant do. Thousands of people now interested in gardening will gladly pay a reasonable price for a plant in which they are interested, and they will visit flower shows and exhibitions in the hope of seeing something new, or something they would like to have in their collection. The hardy-plantsmen, therefore, who make a practice of displaying their specialities at the various exhibitions up and down the country stand an excellent chance of making new customers if they exhibit really choice and well-grown stuff, and set it up with all the art of window dressing. The old style of jumbling plants up "anyhow" at an exhibition is no longer sufficient. The exhibitor adopts various devices, and when space permits he makes miniature herbaceous borders, rock gardens, water gardens, and he arranges his goods in such an artistic way that the would-be purchaser is at once captivated, and longs to produce a similar floral picture in his own garden. This naturally leads not only to the sale of plants, but also to the engagement of landscapemen, who know how to turn a piece of waste land into a smiling flower garden. Many firms now make a speciality of laying out gardens artistically and naturally, and although some amateurs try their untrained hands at the business, they generally have to call in the aid of the man who knows his plants and their nature and uses by everyday intercourse and experience.

A FIELD OF NARCISSUS

(2) A FIELD OF SPANISH IRISES

BULB FARMING AT WISBECH, CAMBRIDGESHIRE

(Mr. J. W. Cross)

While exhibiting is one of the best means of doing business for the grower of hardy plants, it must be remembered that it entails a large expense. The mere carriage of the plants by rail or road, apart from hotel and other expenses, often means a substantial sum, the recovery of which will depend largely upon the weather and upon the class of visitors to the exhibition.

Some growers of hardy plants rarely exhibit, but rely upon the post and advertisements to dispose of their goods. Hundreds of thousands of young plants and cuttings are sent through the post to the most remote parts of the kingdom, to fill orders that have come to hand as the result of reading an advertisement. Some, indeed, spend from £50 to £100 a week during the season in advertising alone, and this will give some idea as to the volume of the trade. Not only are hardy plants disposed of rapidly in this way, but also half-hardy and tender plants during the season, as may be seen by referring to the advertisement columns of the trade and amateur papers.

From what has been said it will be gathered that the great trade in hardy plants of all kinds, and in seeds and cuttings, as well as in bulbous and tuberous plants, is largely done by means of judicious advertising. The plant grower not only supports the newspapers, but he also places large orders with the printers for thousands of catalogues that are issued broadcast, but not without considerable expense. Some of the larger firms issue as many as eighty thousand beautifully prepared catalogues every year, weighing in the aggregate from 90 to 100 tons; while smaller men print and distribute catalogues according to their means. In all cases, however, the General Post Office, the printers, and newspaper proprietors have had the first pick at the seedsman's or hardy-plantsman's purse, and he is left to settle his account with a more or less fickle public.

The Nursery Trade.—This branch of commercial gardening has extensive ramifications all over the kingdom. All kinds of plants, fruits, flowers, and vegetables are grown for sale in the open or under glass, and thousands of gardeners are employed to propagate and grow them. There are many special branches in the nursery trade. Thus some make a speciality of Roses, some of fruit trees, some of ornamental trees and shrubs, some of stove and greenhouse plants, some of Ferns, some of Orchids, some chiefly of forest trees, some of hardy herbaceous perennials and alpines, and rock and water plants—and perhaps not one of these nurserymen ever sends a plant to a market. The nurseryman is quite distinct in his methods of trading from the market grower and the market gardener. He makes a speciality of various classes of plants, and has every nook and corner of the globe ransacked by horticultural travellers, who are on the lookout for any new plant likely to attract attention.

Besides pushing his trade by means of travellers, advertisements, and catalogues, the nurseryman proper also relies largely upon exhibitions. These are held regularly not only in London, where the finest class of trade is done, but in almost every town of any importance in the kingdom,

at different periods of the year. In some cases exhibitions on the Continent are also visited, and in this way some firms have worked up a large international or cosmopolitan trade. These exhibitions naturally cost much money, not only for transport, but for the maintenance and lodging of the necessary staff; and it is essential to reap a good harvest in the way of orders to enable one to pay the expenses and leave a balance on the right side.

Market Gardening and Market Growing.—The business of the market gardener and the market grower is different in a technical sense. The market gardener proper, as a rule, grows fruits and vegetables on a large scale in the same way that the farmer grows corn and root crops. If he indulges in glass at all it is a few frames at the most to raise early supplies of seedlings to put out at the first favourable opportunity in spring; or he may use bell glasses or cloches to protect his early cauliflowers and marrows, much in the same way as the French cultivators do.

Market gardening has been a great industry in the Thames valley for generations, and notwithstanding the operations of the builder, and the enormous growth of the London suburbs, there is still a large area around the metropolis devoted to market gardening. Of course the market gardener is being pushed farther and farther out, but with improved methods of transit, and better roads, the man twenty or thirty miles from London is probably in as good a position as his predecessor was fifty or sixty years ago, when only a dozen miles from Covent Garden. Old market-garden districts like Deptford, Fulham, and Chelsea have been wiped out by the builder, and buildings and roads now take the place of cabbages, rhubarb, fruit trees and bushes that not so many years ago made those neighbourhoods truly rural. This pressure from the centre has naturally driven the market gardener farther out, and such places as Feltham, Ashford, Sipson, Staines, West Drayton, Harmondsworth, Bedfont, Shepperton, Stanwell, and Cranford, in Middlesex, are becoming covered with fruit and vegetable gardens. Kent, Surrey, and Essex are being invaded in much the same way, and there seems to be a tendency to increase the acreage under these crops. From Mortlake to Richmond and Petersham, on the south side of the Thames, market gardens still exist, but it will probably not be for very long. Chiswick, on the north bank, still contains some of its ancient market gardens, and these extend to Brentford, Isleworth, Heston, and Hounslow; but in these famous market-garden areas the builder is rapidly covering the ground with bricks and mortar. The vale of Evesham in Worcestershire has become famous as a centre, not only for the market culture of fruits and vegetables, but also as the first place in the British Islands where "intensive cultivation" as practised around Paris was established. For particulars of this system the reader is referred to Vol. IV.

While the market gardener is seeking fresh fields for his labours, the market grower who brings his crops to maturity under glass has come very much to the front during the past thirty or forty years.

There are now enormous areas of glasshouses erected all round the metropolis, but more especially to the north in such places as Edmonton, Ponder's End, Enfield, Waltham Cross; in the north-west round Finchley, Whetstone, and Potter's Bar; and to the west at Isleworth, Feltham, Hillingdon, Uxbridge, Sipson, and West Drayton. In other parts of the kingdom, notably Worthing and the Channel Islands (principally Guernsey), large areas of ground have also been covered with glass. This has naturally led to the development of other businesses, such as the timber trade and the iron trade. Glasshouses are now built on quite different principles from what they were twenty or thirty years ago, and growers are at last beginning to realize the great value of light to their crops, and to appreciate structures that will allow the maximum amount of sunshine through the glass. Less wood and more glass is now the rule. In the iron trade, enormous quantities of material are used for the manufacture of boilers and pipes; while the manufacturers of paint, putty, and other materials also do a brisk trade with market growers. To these must be added the various gas companies and colliery merchants, who provide thousands of tons of coke or anthracite coal to feed the furnaces attached to the glasshouses.

The crops grown under glass are naturally of a quite different nature from those grown in the open air. They require greater care and skill in cultivation, and frequent changes are made in accordance with the alterations in fashion or the fluctuations of the market. Cucumbers, Tomatoes, Grapes, Ferns, Palms, Aspidistras, Chrysanthemums, bedding plants, Melons, Peaches, constitute some of the chief crops grown extensively under glass, and they are all dealt with in their proper places in Vols. II, III, and IV of this work. Such outdoor crops, however, as Cabbages, Lettuces, Radishes, Mint, Rhubarb, Sea Kale, Dwarf and Runner Beans, Marrows, &c., are also now grown extensively under glass by many to supply the early markets and thus pander to the fashion of having everything in as early as possible before its natural period.

Notwithstanding the numbers of market growers who now send produce to the London and provincial markets, it is astonishing to see the enormous quantities of fruits, flowers, and vegetables that are imported from the Continent and the Colonies. The increased speed of trains and steamboats now renders it possible to bring supplies to market that a few years ago would have been considered impossible. The introduction of the refrigerating system on trains and steamboats has still further aided the introduction of colonial and foreign produce to British markets—one of the surest signs that they are the most lucrative in the world. If they were not, supplies would soon cease, and trade would flow to the markets where the "biggest penny" was to be secured.

The Florist Trade.—There is scarcely a town of any pretensions in the British Islands that does not boast of at least one florist's shop. In large provincial towns there are many, and in the metropolis itself and its suburbs there are many hundreds. The floral trade has developed

enormously during the past twenty or thirty years, and the florists' shops are the main outlets for most of the decorative plants and flowers grown by market nurserymen. It would indeed be a poor prospect for the latter if the business of the florist was interfered with or hampered by increased burdens of taxation. The more florists there are in the country the better for the growers of plants and flowers. Incidentally, the florists' shops are a sign of the general prosperity of the people, because their trade may be regarded more in the light of a luxury of art and taste than as an actual necessity.

The business carried on by the florist is of a varied character. He is an adept at the making of bouquets of all kinds for weddings or Court functions. Wreaths, crosses, anchors, pillars, cushions, and numerous other floral emblems for the departed also come within his sphere of influence, in addition to which he sells masses of cut flowers in a natural state, as well as decorative pot plants, little shrubs, &c. And where the florist happens to be also a nurseryman, he undertakes landscape work and jobbing. In all these operations his raw material consists of plants and flowers of all descriptions, hardy and tender, and he is ever on the watch to invent new designs, or to arrange his flowers, &c., in such a way that they will attract attention and excite admiration. Some of the leading London florists have made their names famous by the taste and original ideas they display not only in the making of wreaths, bouquets, &c., but in the artistic way they decorate or furnish banquet halls, theatres, reception rooms, &c. All important public functions in any town or city lead to business being done by the florist; and he who displays the greatest taste, originality, and industry is the one most likely to be patronized.

The florist and furnishing trade indeed cannot be learned in a day. Many an excellent grower of plants and flowers used in floral decorations would make but a sorry job of it if he had to arrange his own produce for a public function. It takes years to become an expert florist, and in some branches of the trade, such as the making of wreaths, bouquets, &c., women stand as good a chance as men, if not a better. The operator must be not only skilful and quick in "mounting" the flowers on various kinds of wires and "foundations", but must display considerable taste in the arrangement of the individual flowers, and of their effects upon one another. It is quite possible for the choicest flowers to be as easily spoiled in effect in the hands of an incompetent florist as it is for good viands to be spoiled in the hands of an incompetent cook. A skilled florist will produce a finer effect with a few inexpensive blossoms than an unskilled one will with a cartload of choice material, just as some women can dress charmingly at little expense while others will look dowdy in the finest materials and jewellery.

There is no end to learning in the florist's business, and the fashion of to-day may be out of date to-morrow. Great and wonderful changes have taken place within the past thirty years in the way flowers are

arranged. Formerly bouquets were made in a round, flat, and dumpy style, having row after row of flowers arranged in circles round the centrepiece. The whole arrangement was flat and formal, and was finished up with a collar of fancy paper. This heavy style of bouquet has long since disappeared, and a lighter and more graceful arrangement has taken its place. This has been brought about by the introduction of different kinds of flowers and trailing plants, and the different methods of sending them to market. Twenty and thirty years ago nearly all flowers were cut with very short stalks, so that the florist, to produce any effect at all, was obliged to mount many of them on wires to raise them above their neighbours. In these days, however, florists insist on having flowers with the natural stems as long as possible, so that a variety of designs is more easily obtained. The grower who would now send short-stemmed Roses or Carnations to market would find his wares on his hands when the market closed. With some classes of flowers, such as Camellias, Tuberoses, and Eucharis, it is impossible to supply long stems to the individual flowers, and what they lack in this respect must be made up by the florist in other ways.

Amongst the most important of the florist's accessories are wires of various kinds, and moss for the foundations of wreaths, crosses, anchors, and other emblems. The stiffish wires used for mounting flowers are known as stubs, and are of varying length and thickness, according to the purposes for which they are required. Special wires are also used for the mounting of Roses, Camellias, Tuberoses, &c., and it takes some considerable time for the beginner to find out, not only the proper stubs and wires to be used for certain purposes, but to acquire that manual dexterity which distinguishes the expert from the tyro.

The foundations of various sizes and shapes are made of strong galvanized wire by the horticultural sundriesman, so that they will not bend or twist when in use. These foundations are covered with soft moss tied on with string or wire, and into the moss the flowers, mounted on wires or stubs, are stuck. Years ago, before the use of stubs became common, flowers were tied down to the moss foundations, and the general effect was flat and unrelieved. Nowadays, however, flowers can be arranged in various styles—some flat, some slightly raised, some bunched boldly in certain places and forming the *pièce de résistance* of the whole work—all of which variations depend upon the artistic perceptions of the operator. Owing to the more frequent interchange between British and Continental florists now than formerly, constant changes are taking place, and one notices how largely the ideas of the Continental florists are being assimilated by their British brethren, and vice versa.

Popular Florists' Flowers.—Perhaps the florist attaches more importance to the colour than to the form of the flowers he uses in his business. As a rule, flowers with clear and distinct shades of colour are most appreciated; while those with confused tones or lacking in brilliancy are practically useless. A colour that will not show up well at nighttime under

gas-light or electric light is of little use, because a good deal of the florist's art is seen under these conditions.

White Flowers.—Taking the colours all in all, white is undoubtedly the most popular, and enormous quantities of white-flowered plants must be grown to meet the ever-increasing demand. Amongst the most important plants used for a supply of white flowers to the florists the following may be mentioned: Lily of the Valley; *Lilium longiflorum* (*Harrisi*); *Lilium speciosum* or *lancifolium album*; *Eucharis grandiflora*; Camellias; Tuberoses (*Polianthes*); *Freesia refracta alba*; Tulip, La Reine; Roman Hyacinths; Florists' Hyacinth, La Grandesse; *Gladiolus Colvillei*, The Bride; Stephanotis; *Lapageria alba*; Bouvardia; Rose, Niphetos; Gardenias; Carnations; Phlox; Chrysanthemums; Dahlias; China Asters; Stocks; Azaleas; Pink, Mrs. Simkins and Her Majesty; Zonal Pelargonium Hermione (double); Gloxinias; Snowdrops; Paper-white Narcissus; Star of Bethlehem (*Ornithogalum*); *Odontoglossum crispum*; Christmas Roses (*Helleborus niger*); Arum Lilies (*Richardia*); *Hoteia* (*Spiræa*) *japonica*; *Gypsophila paniculata* and *G. elegans*; *Achillea*, The Pearl; Sweet Peas; Spanish Iris; Florentine Iris; Pæonies; *Phalænopsis grandiflora, amabilis, Riemstedtiana*, &c.

Apart from white, flowers of all other colours are utilized in great abundance, and the principal kinds used may be noted as follows: Roses of all kinds; Violets, double and single; Carnations—Perpetual and Border varieties; Daffodils and Narcissi; Tulips; Hyacinths; Gladiolus; Dahlias; Chrysanthemums; Phlox; Forget-me-nots; Zonal Pelargonium Raspail, double scarlet; Orchids such as Cattleyas, Dendrobiums, Oncidiums, Odontoglossums, Lælias, and Phalænopsis.

Trailers.—For "shower" bouquets, festoons, and table decorations it is useful to have certain plants with slender trailing stems and foliage that will not soon wither. Amongst the best plants for this purpose are *Asparagus Sprengeri*, *A. plumosus*, and *A. plumosus nanus* (all known as Asparagus "Ferns"), *A. medeoloides* (or *Myrsiphyllum asparagoides*) far better known to florists as "Smilax". A great trade is done in the trails of these plants, and some growers make a speciality of their culture.

Foliage.—For backing up many flowers used in wreaths, crosses, bouquets, &c., it is sometimes essential to have foliage that will throw the blossoms into greater relief, and a large number of plants are grown for this purpose. Until the various kinds of Asparagus were introduced, the fronds of the Maidenhair Fern were used in enormous quantities for almost everything. Of late years, however, the foliage of other plants has been utilized, and florists now stock in the proper season the leaves of such plants as: Crotons, Maples, Holly-leaved Barberry (*Berberis Aquifolium*), Copper Beech, Ivy, Copper Hazel, Purple Plum, Scarlet Oak, *Galax aphylla*, large-leaved Myrtle, &c., to which must be added for winter work sprays of Mistletoe and of Holly in leaf and berry. There is still a great trade done in what is known as "French Fern" (*Asplenium adiantum-nigrum*), the fronds of which are sold in bunches. The old conventional

ideas, however, are gradually vanishing, and it is now customary to use the natural foliage of any flower that may be used in floral work. Thus violet leaves are most appropriately used with violet blossoms, as holly leaves are the most suitable adjuncts to the scarlet berries. Indeed there is no end to the methods employed by the modern florist to produce a charming effect; and the plant and flower grower who will introduce a new plant, or suggest a novel idea, is looked upon as a floral friend.

Tree and Shrub Trade.—This is a very important branch of commercial horticulture, and one about which the general public knows but little. It may be divided into two principal groups, viz.: (1) that dealing with forest trees, and (2) ornamental flowering trees and shrubs.

In regard to forest trees it is astonishing what an enormous number of young plants are raised every year in different parts of England, Ireland, and Scotland. Those who are under the impression that British forestry is a dead or dying industry have no idea as to the amount of business done in forest trees, and it is a pity that the Chancellor of the Exchequer and the officials of the Board of Agriculture are not better informed as to what is being done in this respect. There are hundreds of capable men, who could not only plant all the waste land in the United Kingdom in a comparatively short time, but who could produce millions of young forest trees annually to fill the gaps that might occur. And yet Mr. Lloyd George, when introducing his famous 1909 Budget, said in reference to the scheme of afforestation: "I am also told that we cannot command the services in this country of a sufficient number of skilled foresters to direct planting. I am advised, and, personally, I am disposed to accept that counsel as the advice of prudence, that the greater haste in this matter will mean the less speed, and that to rush into planting on a huge scale without first of all making the necessary experiments, organizing a trained body of foresters, and taking all other essential steps to ensure success when you advance, would be to court disaster which might discourage all future attempts."

It would be interesting to know whose advice the Chancellor of the Exchequer relied upon when he stated that "we cannot command the services in this country of a sufficient number of skilled foresters to direct planting", but there was no doubt about its misleading character. We wonder what kind of men they are who raise and plant thousands of forest trees annually? Have they no knowledge of the trees they raise, and are they not skilled in planting and growing them? The Chancellor's somewhat misleading statement is calculated to injure the reputation of a large number of skilful and hard-working men who earn a living by carrying out the very duties which the Chancellor was advised were not and could not at present be performed. These men, skilled in the raising, planting, and cultivation of forest trees, may not, of course, be able to pass an examination in Greek and Latin, or in Conic Sections and Trigonometry, nor have they had the disadvantage of a "public-school training"; but they know their business, and if the Chancellor of the Exchequer will only

start the Government Afforestation Scheme at once, he will find plenty of skilful foresters who will see that the preparation and planting of the 17,000,000 acres of waste ground in the United Kingdom are carried out properly.

Raising Forest Trees.—The simplest method of raising these is from seeds. These are collected when ripe in autumn and carefully stored until the spring. In some cases, however, like the Willow, Poplar, Elm, in which the seed ripens early, sowing may take place during the summer months. The seed land is prepared by ploughing or digging, and harrowing and raking, until it is brought to a fine tilth. Drills are then drawn at regular distances apart, varying from 3 in. to 12 in. according to the kind of seed that is sown, each kind being covered with three or four times its own depth of soil, and afterwards lightly rolled. In some cases seeds are sown broadcast over beds about 5 ft. wide, but generally speaking it is more economical, and better for the seedlings, to sow thinly in drills. To allow for cultural attention like weeding, hoeing, watering, &c., the seed-beds should not be more than 4 to 5 ft. wide, with an alley between, so that half the seed-bed may be attended to from one side and half from the other without having to tread upon the soil between the plants.

The forest and other trees raised in large quantities from seed are Oaks, Beeches, Birches, Ashes, Poplars, Sweet Chestnuts, Horse Chestnuts, Elms, Hollies, Hawthorns, Hornbeams, Limes, Mountain Ashes, Planes, Sycamores, False Acacias (Robinia), Maidenhair Trees (Gingko), Willows, Tulip Trees (Liriodendron), and such conifers as the Firs, Spruces, Pines, the Arbor Vitæ, Cedars, Thuyas, Larches, Cypresses, &c.

Apart from the forest trees, there are hundreds of others of a more ornamental character, chiefly used for the decoration of large parks and gardens, public places and squares, streets, &c. These are raised not only from seeds in the same way as forest trees, but in the case of special varieties, or when seeds are not ripened in abundance, they are also raised by means of cuttings, layers, buds, grafts, and suckers. The most important plants in this group and in the forest section are dealt with in Vol. II in the article on "Trees and Shrubs", to which the reader is referred.

Of late years a great trade has sprung up, chiefly amongst nurserymen, in ornamental flowering shrubs, which are grown in pots and gently forced into early bloom in Spring (January to March and April). The principal plants thus grown are Lilacs, Double Cherries, Azaleas, Almonds, Japanese Quinces, Wistaria, Double Plums, *Cydonia Maulei, Pyrus spectabilis, Deutzia gracilis, Staphyllea colchica, Prunus triloba, Magnolia Soulangeana, Forsythia suspensa, Ribes sanguineum,* &c. &c.

A trade also has sprung up again in clipped trees and shrubs of an evergreen character. Such trees as the Box and the Yew, the Poet's Laurel, and others are cut into various shapes, some more or less fantastic—as shown in the photograph (fig. 1). They are usually grown in tubs, and are utilized for what some people call decoration, but others desecration, of large gardens. [J. W.]

Photo. Chas. L. Clarke

Fig. 1.—Clipped Trees and Shrubs

Japanese Gardening.—Although the introduction of the beautiful Japanese plants that now contribute to the charm of British gardens belongs to the distant past, it was not until some fifty years ago that commercial cultivators gave serious attention to the Japanese flora with a view to obtain some other of its members for the further enrichment of our gardens. If until the middle of the last century Japan was not exactly a sealed book to the seeker after new forms of tree and plant life, the restrictions imposed upon the members of other nationalities were such as to render it extremely difficult for them to obtain access to the country, much less to explore meadow or woodland, or plain or mountain, and bring away on their return home the spoils of the exploration. The removal of these restrictions by the opening of the Japanese ports to foreigners rather more than half a century ago gave

the desired opportunity for collecting some of the many beautiful trees, shrubs, and other plants that were likely to succeed under the climatic conditions that obtain in the United Kingdom, and placing them at the disposal of the general body of plant lovers. Then as now the nursery firms of this country were remarkable for their enterprise, and therefore not slow to take advantage of the opportunity thus given them for enriching gardens with new and beautiful forms of plant life.

As a proof of this one example will be sufficient. In April, 1860, the late John Gould Veitch, a member of the well-known Chelsea firm, left England on a voyage to the Far East, and arrived at Nagasaki in the July following. He remained in Japan about twelve months, and during that period he sent home a large number of trees, shrubs, and bulbous and other plants, and of these the greater proportion have proved of so high a degree of value as to obtain a place in gardens generally. Coniferous trees included *Abies firma*, *A. microsperma*, *Cryptomeria japonica elegans*, *Juniperus chinensis aurea*, *Larix leptolepis*, *Picea Alcockiana*, *P. ajanensis*, *P. polita*, *Pinus densiflora*, *P. parviflora*, *P. Thunbergi*, and the varieties of *Retinospora obtusa*. The deciduous trees included the varieties of *Acer palmatum*, the climber *Ampelopsis tricuspidata* (or *Vitis inconstans*), and the plants *Lilium auratum*, *Primula japonica* and *P. cortusioides*. The introduction of so many kinds of first-rate importance within so short a period evinces much enterprise, for travelling in Japan was very different in those days from what it is at the present time. The Abies, Cryptomeria, Piceas, and Pinus represent species that rank high in their respective genera, and the varieties of *Retinospora obtusa* are so diversified in form and colour, and withal so attractive, that they have throughout the period that has elapsed since their introduction enjoyed a high degree of popularity and have been freely used in the creation of garden scenery.

The varieties of *Acer palmatum*, in the varied form and colour of their elegant foliage, are recognized as forming a group of small-growing trees of immense value for garden decoration; and *Ampelopsis tricuspidata* is used more largely in clothing wall surfaces than all the other climbers combined, and it contributes in no small degree to the amenities of town life. The richly coloured *Primula japonica* continues to be highly appreciated as one of the best of the moisture-loving plants for fringing streamlet and pool in shady positions, and as the result of the activities of various commercial horticulturists the varieties of *Primula cortusioides* have been so multiplied as to form a large group in which there is so great a range of colour as to greatly enhance their value for various decorative purposes both under glass and in the open.

The plants thus briefly enumerated rapidly came into favour. They were largely used, and soon made an impression on the scenery of gardens where novelties of merit received a welcome. They greatly enhanced the interest and attractions of gardens in which they were given a place, and as a result they greatly stimulated an interest in Japanese plants, and

gave rise to so strong a demand as to tax severely the resources of nurseries for a long series of years, and have an immense influence for good upon a great industry. They had another effect in their relation to the garden, and that was to quicken an interest in rare and beautiful plants from other parts of the world, by showing that there were subjects other than timber trees and the common laurel suitable for furnishing the garden.

In the case of *Lilium auratum* there was a brisk demand for bulbs at a comparatively high rate, and when it became possible to supply them at a price which placed them within the reach of practically all owners of gardens, the demand increased to an enormous extent. For forty years or more the importations of the bulbs of this Lily have annually been on such a large scale as to represent a trade of considerable importance and to occupy a prominent position in the business of those who are concerned with the distribution of bulbs. *Lilium longiflorum*, which was introduced to this country in the year previous to John Gould Veitch's voyage to Japan, has enjoyed a higher degree of popularity than even that of *L. auratum*, not because of its flowers being superior in beauty, but because of their adaptability for decorative purposes. To the florists they are of immense value, for they can be used more or less successfully in wellnigh all forms of the decorative art, and with the aid of the refrigerator in retarding the bulbs they can be had in abundance at all seasons of the year.

British cultivators are no longer wholly dependent upon Japanese growers for their supplies of bulbs, but they annually obtain large importations from them. The demand for this beautiful and useful Lily is very great, and the importation and distribution of the immense numbers of bulbs that are annually required in market-growing establishments and private gardens has become so important a detail of commercial horticulture that one could wish statistics showing the exact quantities that annually reach this country from Japan were available. *Lilium speciosum*, which also forms an important part of the trade in Lily bulbs with Japan, was introduced from that country in 1833; but since that year the Japanese growers of Lilies have sent us varieties of this species which are so superior in the size, form, and colouring of their flowers as to surpass those of the typical white and coloured forms and to render them of quite secondary importance.

Of much interest is *Iris Kœmpferi*, which was introduced to this country from Japan in 1857, and attracted much attention when the large handsome and richly coloured flowers were first presented to public notice at the exhibitions, and began to make their appearance here and there in private gardens. For a time they failed to make the headway that was anticipated, and this was in a large measure due to the cultural details being then imperfectly understood. Many of those who planted this Iris in its varied forms failed to recognize the fact that to achieve success the roots must have the run of a rich and moist soil, an abun-

dance of moisture being especially necessary during the season of growth. Hence large numbers were planted in beds or the mixed border, without reference to their special requirements in the matter of food or moisture. The growth was consequently unsatisfactory, and in course of time their cultivation was greatly reduced. Within the past few years there has been a great revival in the interest evinced in this and other of the Japanese Irises.

The lessons that the Japanese growers have been able to teach us have been taken to heart, and moist positions are selected for the moisture-loving Irises, and, if these cannot be provided, care is taken to maintain the soil in a thoroughly moist state throughout the whole period when the plants are in an actively growing state. The influence of the Iris gardens of Japan has been felt in many gardens of this country, and in not a few, large plantings have been made on the lake side and along the margin of pools, and constitute delightful features. These examples are of interest as showing that if we cannot have displays of Irises equal to those which have made the gardens of Hori-kiri famous, we can with their aid have in this country floral pictures of wondrous beauty.

Among the Japanese trees and shrubs that have been introduced but have not as yet been planted largely, mention may be made of *Magnolia hypoleuca*, which attains noble proportions, but does not produce its handsome flowers freely until it has attained a large size; the Japanese Horse-chestnut (*Æsculus turbinata*); the elegant *Styrax japonicum*; *Betula Maximowiczi*, a handsome Beech remarkable for its large leaves and yellow bark; *Quercus acuta*, *Q. glabra latifolia*, two Evergreen Oaks of merit. Then there is *Daphniphyllum glaucescens*, one of the most handsome of evergreen shrubs, and *Vitis Thunbergi*, which surpasses in brilliancy of colouring *V. Coignetiæ*, long so popular for clothing trellises, wall spaces, and tall pillars.

With a fuller knowledge of the distinctive characteristics of the many beautiful trees, shrubs, &c., that had been introduced from Japan, and the increased facilities for becoming acquainted with the various phases of garden design that had long found favour in that country, it is not surprising that a strong desire should have been felt by many owners of gardens within the British Isles to create gardens more or less in accordance with Japanese ideas. Practical expression has in numerous instances been given to this desire, and, as might have been expected, with varying results. Where the principles governing the making of gardens on the lines followed by the Japanese landscape gardeners have been acted upon as closely as circumstances would permit, the result has been a distinct, interesting, and pleasing addition to the pleasure grounds. On the other hand, where but scant attention was given to principles, the results have not been altogether satisfactory.

The Japanese garden, as we understand the term, is not a swamp, as suggested by some of the gardens that have come under our notice. Neither is it a lake surrounded by an irregular belt of trees and shrubs

3)

JAPANESE GARDENING

TWO VIEWS OF JAPANESE GARDENS ERECTED AT LONDON EXHIBITIONS
(Jas. Carter & Co.)

and a winding walk, with, it may be, a bridge or stepping stones to cross it at the narrowest part. The Japanese garden does not consist of one or two features, but of many, and one of the distinguishing characteristics of the Japanese landscape gardener is the skill with which he combines the features of, it may be, a whole countryside, in an area of quite moderate dimensions. Another attribute of his skill is the success that is achieved in maintaining the relative proportions of the several features, and also of the trees and shrubs with which the garden is embellished. In accomplishing this important object he has in many instances to use trees, ornaments, &c., of so small a size as to suggest to the Western mind that the garden is intended as a model on a reduced scale rather than for the enjoyment of the owner.

The garden in Japan is regarded from a somewhat different standpoint from that which we consider it in this country. Here, to state the case generally, we provide a garden adapted to the requirements of the plants in which the owner is specially interested, with such embellishments as may be considered necessary; to the Japanese, plants primarily exist for the assistance they are able to render in the production of artistic effects, and are utilized accordingly. One of the principal rules governing the work of the landscape gardener in Japan is to follow nature as far as is practicable, and to arrange the arborescent and other forms of plant life in their natural associations. That is to say, plants which in a state of nature have their home on the mountain side are not to be brought down to those parts of the garden which represent the lowlands, and, it may be, used in the formation of a flowery fringe to running stream or silent pool. In like manner the plants that luxuriate in the moist conditions that obtain at the lakeside are not used in the clothing of the side of a hill or mimic mountain. The Japanese garden artist would appear to give ready adherence to this rule, for he can readily include in any given design the characteristic features of any given portion of the native landscape.

Another rule of some importance is to avoid as far as practicable the planting of deciduous trees, with a few exceptions, in the more prominent positions of the garden. The exceptions are deciduous trees remarkable for the beauty of their flowers, such as the Cherries and Plums, which are not only immensely attractive when yielding their wealth of flowers, but are great favourites with the Japanese. If it is intended to plant a tree near the end of a bridge, one should be selected which will spread its branches over it, and cast a shadow on the water. It is not considered in accordance with the canons of garden-making to show the whole of the volume of water tumbling over rocks, and therefore it is enjoined that in selecting a tree for planting alongside a cascade that it will throw its branches partly over the rushing water.

Shade-giving trees are considered the most suitable for planting near seats and tea houses, and Pines are the most generally selected for the purpose. Much the same rule applies to the planting of trees by the

side of ponds and other small water areas, the object being to obtain a cool retreat during the summer's heat. The selection of positions for trees in the gardens is considered by the Japanese authorities as a matter of much importance, and they feel, as do those in this country who have had experience in such work, that when trees are planted without the exercise of sufficient judgment the desired effect is lost.

For a long period Pines were the favourite garden trees, and they were trained to form round heads or to some quaint shape to give a distinctive appearance to the spot in which they were placed. Of late years Western ideas would appear to have had some influence upon the Japanese, for within the past decade or so trees more or less natural in growth have come into favour, and the trees with formal heads or contorted branches are no longer fashionable.

The Japanese Maples, of which there are now so many beautiful forms in cultivation, are not always a complete success in British gardens, and this is due in many instances to a failure to plant them in positions most favourable to their full development. The Japanese, having a full knowledge of the elegance that characterizes the habit of these trees when growing under natural conditions, and abundant opportunities for enjoying the glorious colour effects produced by their leaves when the breath of autumn has passed over them, freely use them in the creation of garden scenery. They by no means limit their selection to the kinds that do not take on their rich colouring until the summer months have run their course, but group with freedom the many fine forms of *Acer palmatum* that in the diversity in the form and colour of their leaves afford a rare opportunity for the garden artist to produce colour effects of the most beautiful description, extending from within a short time of the bursting of the buds to the fall of the leaf. These Maples are of much value in gardens, whatever may be their design, and particularly in those of small size; and although the demand for them continues to be great, there is room for an acceleration in the rate at which they are being planted.

The free use of stone in the making of Japanese gardens is a point of much interest, and while it may not be regarded as of so much importance as the trees with which the garden is furnished, sufficient care and attention are bestowed upon its selection to ensure every piece being suited to the position in which it is to be placed. Especially noteworthy, also, are the stone ornaments, of which the lanterns of stone are the most important. These lanterns may be of granite, sandstone, or limestone, and they take us far back into the distant past. For many centuries they were exclusively associated with the temples that have a prominent place in many parts of the country; but in the course of the development of the landscape art some of the leading exponents conceived the idea of using them in the adornment of the garden, and within a comparatively short period their use became general.

Stone lanterns are no longer confined to Japan, for larger numbers are annually imported, and many are the British gardens wherein several may

be found. These lanterns differ considerably in design, and there is no difficulty in selecting one that is well suited to the position it is to occupy, whether it be by the waterside, alongside the bridge of stone, or for forming a contrast to the brilliant colouring of the Azaleas or Irises, or the feathery growths of Bamboos and tall-growing grasses. It is one of the canons of the landscapist's art that these lanterns should be partly sheltered by trees, either at the back or front.

In the water scenery that usually has a place in Japanese gardens stepping stones are freely used, and form walks that wind through the water garden and afford an opportunity for closely inspecting the Water Lilies, the Lotus, the Irises, and the many other beautiful plants that thrive in or near water. In some of the more extensive gardens bridges of stone are provided for crossing the deeper waters, but the quaint semi-circular bridges of wood which are now so well known are the most general. The tea house is an essential feature of the Japanese garden, and it may be mentioned that it is usually so constructed of Bamboos or light strips of wood as to allow the air to circulate freely through it, and it is assigned a position on the bank of a lake or pond, on a prominent island, or in some other part of the garden where scenes more or less beautiful can be readily seen.

An essential feature of the Japanese garden is its bamboo framework clothed with the Wistaria, which in its season gives a wealth of the long pendent racemes of blue or white flowers; and even if the Wistarias fall short of the magnificent specimens at Kameido, a suburb of the city of Tokio, they afford displays of wondrous beauty. What has been accomplished in Japan in the cultivation of Wistarias may be done in Japanese or indeed any other gardens in this country. Not less noteworthy for their value in beautifying the gardens of Japan are the double-flowered Cherries, such as *Prunus pseudo-cerasus fl.pl.*, which are planted freely, and annually produce delightful displays. All the best forms that are grown in Japan are in trade collections in this country, and it is much to be desired that with the increased attention that is now given to Japanese gardens they may be planted by the dozen, instead of singly, as is now usually the case. [G. G.]

SECTION II

The Science of Plant Growing

§ 1. SIMPLE AND COMPLEX CELL LIFE

The successful cultivation of plants requires a close familiarity with their likes and dislikes, a knowledge of the conditions of their existence, and how to meet those conditions to the best advantage of the cultivator; for the requirements of man are not always identical with the objects of the plants themselves. By dint of practice alone and close application to the art for a series of years one may become sufficiently expert to grow a limited number of kinds to great perfection, but the field for experiment and improvement is boundless in the domain of gardening. Not merely are there plants, flowers, fruits, and vegetables with which one is familiar, but new ones are constantly arising, differing in some respect from those that preceded them; and hundreds of others, whose cultivation is an undetermined quantity, or may have been known to the successful growers of bygone times and since forgotten, may be placed under the charge of the gardener. The traditions of the past have not merely to be maintained, but the gardeners of the present have to continue the forward march of improvement, by introducing better methods of cultivation wherever opportunity occurs, by improving the fruits, flowers, and vegetables already under cultivation, and originating new ones by the various means and methods at command. The field of enquiry is wide enough for every class of worker, and the practical cultivator may avail himself of the assistance at his disposal from various sources by acquiring a knowledge of the structure and nature of plants, just sufficient to enable him to comprehend the meaning of the information imparted by the more scientific worker.

Simple Cell Life.—A good conception of plant life in its simplest form may be obtained by an examination and study of some of the lower organisms, such as the green scum to be seen on damp walls or the trunks of trees, where the water runs down during rain. If a minute particle of this green matter (*Protococcus viridis*) is put in a drop of water and placed under a high power of the microscope, it will be seen to consist of numerous tiny green bodies of various sizes, invested by

a colourless envelope or cell wall. Each individual constitutes a complete plant. The interior is filled with a particle of granular, jelly-like matter, stained green. This jelly-like substance has been named *protoplasm*, and, as it is present in all living plants and animals, it is considered the *seat of life*. It is the essential part of the plant, as we shall see presently. When any of the cells has reached full size, it divides into two equal parts, which become separate individuals, and repeat the history of their parent by feeding, growing, and again dividing. Those who would see this process must needs burn the midnight oil, for one-celled green plants manufacture food from the atmosphere by day in preparation for dividing by night. Rain brings down many of these plants from the roof-gutters of the house, and if a drop of water from the water butt is examined in summer or other suitable time it will be found to contain more or less numerous organisms, some consisting of a particle of green jelly, without the cell wall, and larger ones with an investing wall, but both sizes moving about rapidly. The movement is due to the rapid vibration of two slender thread-like portions of the protoplasm, without colour, and therefore invisible till something is put in the water to bring the organisms to a state of rest. After a time they lose these filaments, and become surrounded by a cell wall, like those on the damp wall. From the damp wall, or from the water in the butt, these lowly plants absorb their food, or rather the raw materials from which they manufacture it. Already we can see that the cell wall can be dispensed with as so much dead matter, while the naked protoplasm is still termed a cell, and is equally an individual plant.

The Yeast Plant (*Saccharomyces cerevisiæ*), such as is used by the brewer, if put in any clear liquid containing suitable food (malt, for instance), the liquid, if stood in a warm place for some hours, will become cloudy or muddy, this being due to the rapid multiplication of the Yeast Plant. The temperature of the fermenting liquid is raised as a result of the chemical changes being brought about in the constitution of the liquid by the Yeast Plant. If a drop is examined under the microscope, the plant is seen to be oval, smaller than the Protococcus, but without the green colouring pigment of that, showing that it belongs to the great group of Fungi. It is also rapidly multiplying by budding at one end. The tiny protuberance or offset grows to nearly the size of its parent, and drops away as a new individual.

The "clubbing" of turnips, cabbages, cauliflower, and other members of the Crucifer family is due to another fungus, which lives within the roots during summer and other mild periods, causing great swellings to arise. At this period each individual multiplies rapidly, and rests enclosed in a cell wall of its own during winter; but with a rise of temperature in spring the protoplasm quits the cells and unites in a jelly-like mass, which moves through or over damp soil in quest of fresh plants to attack.

From these three plants it will be seen that the protoplasm possesses

certain properties. They can absorb food materials, manufacture the food, breathe, give off certain ingredients as waste products, reproduce themselves, and in two cases are possessed of motion, the capability of which resides in the protoplasm itself (fig. 2). The Protococcus can manufacture its own food from raw materials, by reason of the presence of green colouring matter under the influence of light. The Yeast Plant must be supplied with malt, grapes (in wine-making), or some other food already in an organized form. As the club-root fungus (*Plasmodiophora brassicæ*) is also colourless, it must have organized food, and, as it feeds upon living plants, it is a parasite. All of them absorb oxygen to give them energy, and as it combines with some of their substance, carbon dioxide is given off. The process is equivalent to breathing or respiration, as in animals, and is absolutely essential to all living things.

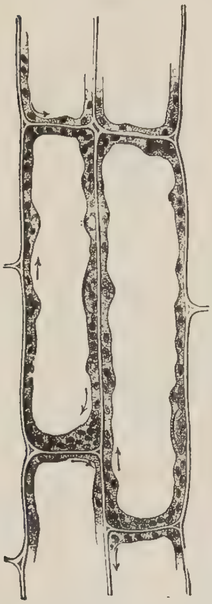


Fig. 2. — Protoplasm Streaming in Cells of Vallisneria in Direction of Arrows

§ 2. STRUCTURE OF THE HIGHER PLANTS

The Growth of a Cell.—The three plants already considered consist of a single cell, varying chiefly in size during their lifetime. Other plants, in an ascending scale of organization, consist of more or less numerous cells united in a variety of ways to form the plant body, either in the form of filaments, or flat plates of cells, as in freshwater or marine algæ. The larger seaweeds form a tissue resembling stem and leaves, but a true stem and leaves are first met with in Mosses and Sphagnum. The Ferns are still more highly organized, by having true roots, stems, and leaves. The flowering plants are the most highly organized, and gardeners are chiefly concerned with them. The tiny Duckweeds, which cover still ponds in summer, are flowering plants of very exceptional structure, for they consist merely of a small mass of green cells, with one or more root hairs from the under side. The smallest of all (*Wolffia arrhiza*) has not even a root hair. The tallest tree and the smallest plant, amongst flowering subjects, consist alike of an aggregation of cells, built up in some definite form, according to the kind.

A full knowledge of plants may be obtained by a study of protoplasm and its protective covering—the cell wall—together with their behaviour when acted upon by light, heat, air, and moisture. A very young cell may be taken from the leaf of an apple tree, when beginning to unfold. It may be oval or nearly round. Under a high power of the microscope the wall appears double, but each individual has its own wall, and the other is the wall of the cells that abut on the one under

examination. The interior at first is entirely filled with protoplasm, in the centre of which is a denser, oval body—the *nucleus*—consisting of a granular groundwork of protoplasm, denser at its margin, and having a fibrillar network of granules embedded in it. The nucleus plays a very important part in the division of full-grown cells. As the cell increases in size, cavities make their appearance in the protoplasm, filled with cell sap and air, and this continues till the cavities unite and the protoplasm can only form a lining to the wall, with a few bridles connecting it with the layer of protoplasm surrounding the nucleus in the centre (fig. 3). Streaming movements of the protoplasm may often be observed in the living cells of various plants (the direction being indicated by arrows in fig. 2). The large granules to be seen embedded in the protoplasm are *chlorophyll* or leaf green. The further history of this cell depends on whether the tissue requires more cells or not for its full development. If it does, then the nucleus elongates into spindle form, the protoplasm forms a mass at each end of the spindle, the two masses being joined by threads. A layer of protoplasm (the cell plate) then extends across the cell from wall to wall, and from this layer a new partition is formed simultaneously and continuously. Thus two cells are formed. The common partition later on splits into two, so that each daughter cell has

Fig. 3.—Isolated Cells (1 and 2) with and (3) without Nuclei—highly magnified

Fig. 4.—Changes in the Protoplasm of the Cell Nucleus during its Division

1, The Nuclear Fibrils distributed through the whole Nucleus. 2, The broken-up Nuclear Fibrils arranged as the Nuclear Plate. 3, The elements of the plate separating from one another. 4, The same elements forming two skeins at the poles of the Spindle. (After Guignard.) Very highly magnified.

its own complete wall and a half of the original nucleus (fig. 4). If the full-grown cell does not intend to divide, the remainder of the protoplasm is used up in thickening the walls, or is drafted away into younger and growing cells. The empty cell is now dead for all time coming, though it may exist for a thousand years or more, if it forms part of the stem of a giant *Sequoia gigantea* of California. The cell wall at first consists of *cellulose*, a substance closely allied to starch and sugar, all three being made up of the chemical elements carbon, hydrogen, and oxygen, in different combinations, and all becoming black when burned.

Changes in Cell Walls.—Although the cells of the higher plants may be all very much alike when they begin life, they vary immensely in size, shape, and structure by the time they reach full development, their ultimate construction being dependent upon the functions they have to perform for the wellbeing of the plant. The most common change is the thickening of the cell wall internally, by successive layers of cellulose, till the internal cavity is nearly filled up, and the cellulose gets converted into wood (fig. 5). The cells of the pith remain thin-walled (fig. 6). Those on the outside of the trunk of the Cork tree, Elm, Ash, &c., get thickened like those of the wood; but in this case the material is converted into cork, which is very light and almost impermeable by water.

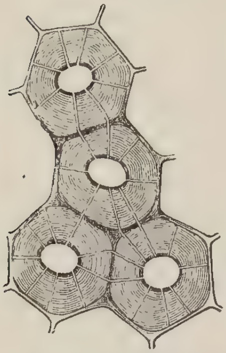


Fig. 5. — Section across Wood Cells, showing concentric layers of woody matter surrounding a central cavity —Scolopendrium

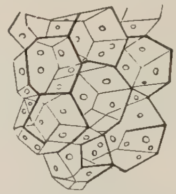
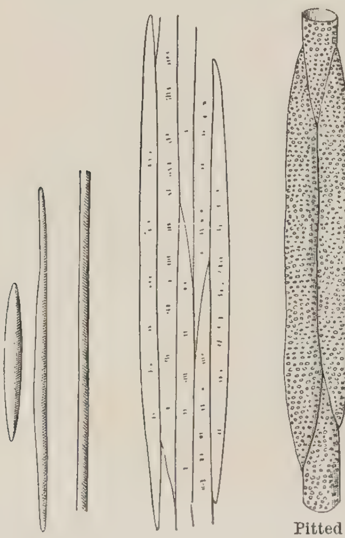


Fig. 6.—Elder Pith, consisting of aggregations of Cells—magnified

A thin layer on the outer face of all leathery leaves, like those of the India Rubber and Palms, forms the *cuticle,* and is also of the nature of cork.

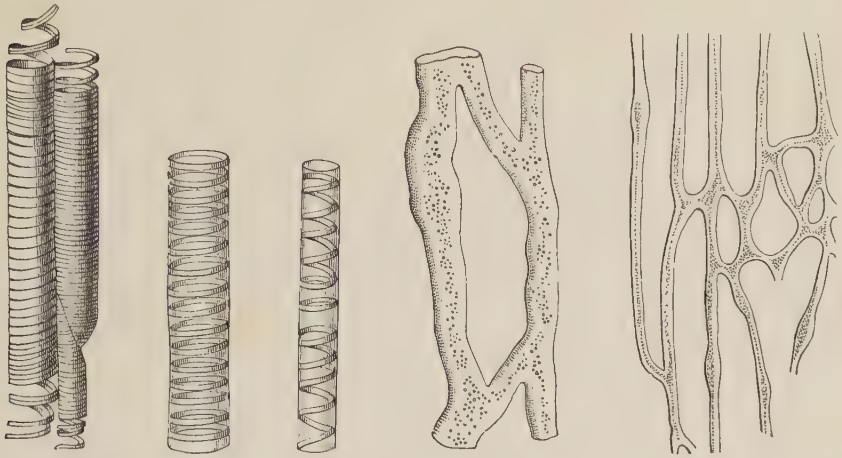
Various Forms of Cells.—With the exception of lowly plants like the duckweeds, the flowering plants generally furnish examples of cells of great variety of form and length. Those which become thread-like, but thickened internally, are termed wood cells (fig. 7), but wood fibres when they become pointed at the ends, with the thin portions spliced or overlapping, so as to form continuous masses of wood (fig. 7). The thickening is by no means always uniform, for small spots are left unthickened in pinewood, and such are known as pitted wood cells (fig. 7). The thickening may take the form of single or double spiral bands in the stems of Melons and Cucumbers (fig. 8), ring-like bands, or a mixture of annular and spiral ones (fig. 8). In ferns the bands unite in the form of a ladder. These elongated cells may be placed end to end and the partitions broken down, thus forming continuous vessels, like a hose pipe, for the rapid conveyance of liquids. Sieve tubes are formed in the inner bark of stems by the dividing plates of vessels becoming perforated by small openings. Plants with a milky juice, like the Lettuce, Dandelion, and India Rubber, have cells which join in a variety of ways and break down the inter-



Tracheids Fibres Pitted Tracheids

Fig. 7.—Wood Cells

vening partitions, becoming continuous and forming what is known as laticiferous tissue (fig. 8).



Melon—Spiral Vessels Annular Vessels Spiral and Annular Vessels Celandine—Laticiferous Tissue Dandelion—Laticiferous Tissue

Fig. 8

Plant Tissues.—All the above forms of cells and many more unite in certain definite relations to one another, forming a tissue (fig. 9). Most flowering plants, Ferns, Lycopods, and Selaginellas have representatives of various forms of cells, wood fibres, and vessels in their tissues, and are spoken of as *fibro-vascular* plants, and constitute the most highly developed members of the vegetable kingdom. A mushroom is not a fibro-vascular plant, as it is made up entirely of branching threads of thin-walled cells.

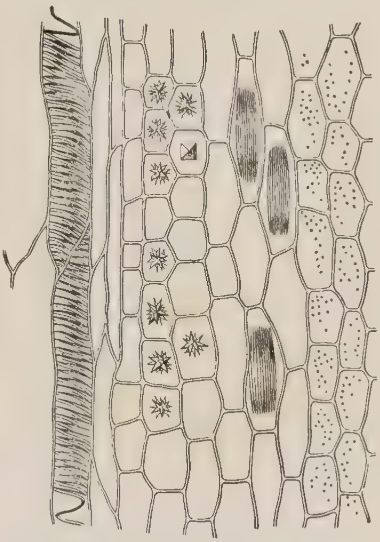


Fig. 9.—Cut illustrating various tissues. To the left Spiral Vessels, followed by long Conducting Cells. These are succeeded by Cellular Tissue or Parenchyma. In some of the square cells are Crystals of Oxalate of Lime. In the longer cells are groups of Needle-like Crystals called Raphides. To the extreme right are Pitted Cells.

Uses of Different Cells. — The thickened outer cells of leaves and young stems are of a protective nature, so far as the cuticle is concerned, while the interior is thickened to impart strength. Wood fibres give rigidity to the stems of herbaceous plants and in a greater degree to trees, which have the greatest number of them; and they, in conjunction with the continuous tubes or vessels, serve for the rapid conveyance of liquids, containing ingredients of plant food, as well as elaborated food being carried to the points of growth or to be stored. The laticiferous

tissue is more obscure, but some of the contents are of the nature of stored food. Some cells are set apart entirely for the purpose of marrying and reproducing the plant. The other cells have their respective duties, and have neither time nor opportunity for this. [J. F.]

§ 3. PLANTS OF DISTINCTIVE CHARACTER

Plants with Chlorophyll.—Most plants with which the gardener has to deal contain *chlorophyll* or leaf green in their leaves and the superficial tissues of their stems, at least during the first year. It consists of a green pigment colouring the large granules that develop it and lie embedded in the protoplasm, but are capable of shifting their position if the light is too strong for them. These green granules, under the influence of sunlight and electric light, are the agents by which all raw food materials are chemically changed in character and converted into organized material suitable for building up the plant body and enabling it to store food for future use, or to provide for its offspring. The light must be accompanied by the other necessaries of plant life, such as heat, air, and moisture. Green plants are thus able to manufacture their own food and lead an independent existence. Crotons, Dracænas, Coleus, and other plants with highly coloured leaves have chlorophyll in their tissues, but this is obscured by the presence of other colouring matters, diffused through the cell sap.

Plants without Chlorophyll.—Amongst flowering plants many species, including the Broomrape (Orobanche) that lives attached to the roots of Clover, and the Dodders (Cuscuta) that live on Clover, Nettles, Hop, and other wild plants, have no chlorophyll in their tissues, and cannot manufacture their own food. They must needs attach themselves to the roots or stems of certain green plants and absorb their food in an organized form, thus robbing and injuring their hosts to a greater or less extent. The Broomrape sometimes attaches itself to the roots of Pelargoniums in pots, and one of them, kept under observation by the writer, was allowed to flower, The result was that the Pelargonium was stunted in growth and failed to recover itself, even after the parasite was removed. Such plants are termed *parasites*, because they absorb their food from living plants. The great group of fungi have no chlorophyll in their tissues, and many of them are parasites, like the Club-root fungus of Cabbages, the Mildew and Rust of Roses and Chrysanthemums, the Rust and Brand of Wheat, and many other cultivated plants. A large number of them are very minute, one-celled, and capable of producing diseases in plants, man, and other animals. In these two latter cases they owe their existence indirectly to green plants as the first and only manufacturers of organic food. On the other hand, many fungi are harmless, because they live upon dead and decaying plants and animals, and are termed *saprophytes*. The Mushroom is one of them, and lives upon fermenting manures and other decaying matter. So far it is the only plant without chlorophyll, that is

of any importance to cultivators in this country. All fertile soils swarm with minute, one-celled fungi or microbes, living upon dead matter and converting much of it into a soluble form, suitable as food for green plants. In a word, they are the agents alike of decay and fertility, preparing the soil, the manure, and leaf heaps for the use of the higher plants.

Lichens are composite plants, consisting of a fungus and a small green alga, working in co-partnership for their mutual benefit. Even some of the higher plants, including several forest trees, have messmates or co-operators amongst fungi, large enough to be seen by the naked eye (fig. 10). The fungi closely invest the fibrous ends of the roots and absorb the food they require from the trees. On the other hand, some of the waste products of the fungi are required by the trees to complete their bill of fare. It is not yet determined to what extent this co-operation prevails among cultivated plants, but some plants difficult to cultivate may really require this kind of assistance. It is well known that Rhododendrons and other plants belonging to the same family like a peaty soil and hate lime in any form. In all probability the lime destroys the microbes in the peat that are essential to the welfare of the Rhododendrons.

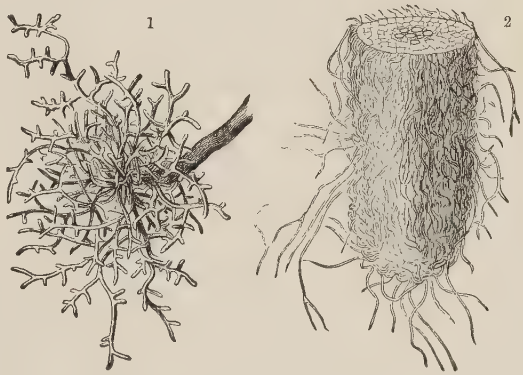


Fig. 10.—Illustration of Co-partnership or Symbiosis

1, Roots of the White Poplar with Mycelial covering. 2, Tip of a Root of the Beech with closely adherent Mycelial covering; × 100 (after Frank). In these cases the Mycelial threads on the roots are of fungous origin, deriving nourishment from the roots on which they grow, but at the same time supplying food material to the roots.

Desert Plants.—Echeverias, Crassulas, and Aloes, from South Africa and Mexico, have fleshy stems and leaves. Cacti, including Epiphyllums from Brazil, Mamillarias and Phyllocacti, from Mexico and other warm and dry parts of America, are also fleshy but have dispensed with leaves to economize their liquids. In their native habitats they get very little rain, and make a point of storing up what they do get, while their structure is such as to prevent the liquids from escaping too freely. Under cultivation many of them enjoy liberal treatment in summer, when the temperature is high and they are making their growth, but they must be kept relatively dry in winter when at rest and the light is bad. With few exceptions they like a relatively high temperature even in winter. They cannot give off moisture like thin-leaved, green plants, consequently water must be withheld almost entirely during winter, otherwise they would decay wholesale. A gardener can readily diagnose a plant of this character, without knowing its name or from what country it comes, and give it the proper treatment accordingly.

Other plants of dry countries produce hard and wiry leaves, like the Grass tree of Australia (Xanthorrhœa), and must likewise be kept on the dry side during winter. The Rushes (Juncus) of our marshes and river banks belong to the same family, but their stems are very largely made up of loose, spongy tissue, surrounded by a thin layer of more solid structure, almost like a skin. They are therefore capable of giving off large quantities of water at any time when circumstances require it. Some plants of dry climates and arid soils and situations clothe themselves with a more or less dense coating of hairs; and in proportion to the density of this covering must they be kept dry in winter, otherwise they would sooner or later get into an unhealthy condition and ultimately perish. The roots are usually the first to suffer from an excess of moisture, but the functions of the leaves and other parts also get deranged. The common Stock, in a wild state, inhabits dry chalk cliffs, and all parts of the stems, leaves and calyx are densely covered with star-shaped, branching hairs. Seedlings under cultivation are extremely liable to damp off while quite young, if kept too close and moist in the seed pans or boxes. The excessive moisture renders them liable to attack by the "damping-off" fungus (*Pythium debaryanum*). It is not usually regarded as a desert plant, but it serves to explain a similar difficulty when brought under cultivation from its dry, wild habitats.

Clammy-leaved Plants.—At first sight these may not seem peculiar, when Petunias and Salpiglossis are mentioned, for there are many other examples under cultivation. They are plants, however, which delight in sunshine and flower best in dry weather. The writer has seen Pelargoniums and other plants remain stunted and lose their foliage in a dry garden on the chalk formation, in a droughty summer, while Petunias, Gaillardias, and other clammy-leaved plants were the only flowering subjects in the beds. While young and making growth they enjoy fairly liberal watering, with a moist atmosphere, but to bloom freely they must have plenty of light and air, and be kept dry overhead. The viscid hairs with which they are covered enable them to recuperate themselves during the night from the deposit of dew in the open ground.

Insectivorous Plants.—Many plants, whose root system is not well developed, or which live in swampy places, where they have difficulty in procuring a sufficiency of nitrogen in the usual way, have evolved some peculiar contrivances for eking out the supply. The Sundews (Drosera), Venus Fly-trap (Dionæa), Pitcher Plants (Nepenthes), (fig. 41). Butterworts (Pinguicula), and Bladderworts (Utricularia), belong to this class, and many of them are cultivated. By various means they manage to capture and detain insects and other small creatures, which they digest or dissolve, absorbing the nitrogen. The Sundew (fig. 11) develops on the upper surface of its leaves numerous tentacles, each terminated by a sticky gland. Flies alighting upon a leaf get held fast by the viscid matter, while the other tentacles close upon their victim. The protoplasm now forms a "ferment", and the liquid is spread over the

PERPETUAL CARNATIONS

1. Carola. 2. White Perfection. 3. Victory. 4. Enchantress

(Half natural size)

fly till dissolved, when the juices are reabsorbed. A stone or other object would cause the infolding of the tentacles, but if such objects contain no nitrogen the tentacles soon unfold, without having produced any chemical changes in the protoplasm, thus proving that nitrogen was the element of food required.

Climbing Plants.—The Convolvulus, Wistaria, and Scarlet Runner are

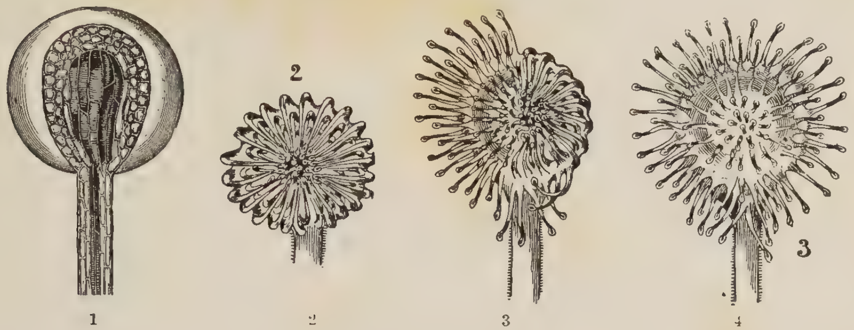


Fig. 11.—To show contraction induced by the contact of insects. Tentacles on Leaf of Sun-dew (Drosera)

1, Glands at the extremity of a Tentacle; × 30. 2, Leaf with all its Tentacles inflexed towards the middle. 3, Leaf with half the Tentacles inflected over a captured insect. 4, Leaf with all the Tentacles extended. 2, 3, and 4 × 4.

examples of plants that climb by twining their stems round some supporting object. If the top or free end of a Scarlet Runner is observed at different times during the day, after it has commenced to run, it will be seen to be swinging round in a wide circle, and should it chance to touch a stake, string, wire, or other support, it commences immediately to coil tightly round the same and to make rapid progress. The stem is sensitive to contact and this sensitiveness resides in the protoplasm, being one of its properties. Scarlet Runners grown in the field without stakes often twine round one another, but without proper support they never attain the length of which they are capable, nor do they produce so heavy a crop. The saving of labour and the extra cost of stakes are the chief reasons for this method of culture. Sweet Peas, garden Peas, Cucumbers, Melons, Vines, and others climb by special structures known as tendrils. The leaf stalks of Clematis and Tropæolum twist round supporting objects in a similar fashion, and they as well as tendrils are sensitive to contact.

[J. F.]

§ 4. THE ROOT AND ITS WORK

The Primary Root.—The first structure that emerges from the interior of a germinating seed is the primary root or radicle, which goes perpendicularly down into the earth. If the minute structure of the tip of this is examined it will be seen to consist of very small square cells at and behind the growing point (fig. 12). Around and in front of this is a layer of brick-shaped, corky cells, most of which are empty and dead. This is

the root cap, which is intended to protect the tender growing point as it pushes its way amongst the particles of soil. The nature of a young root may readily be seen by filling a punnet with light sandy soil and scattering some Mustard seed thinly over the top. Stand it in a warm, moist, shady place for a few days till the seed germinates, and then in a well-lighted position. From the sides of the radicle numerous hairs arise, enter the soil in a horizontal direction, and place themselves in close contact with the particles of soil (figs. 13, 14, 15). These are the root hairs, and their function is to absorb water containing food in solution. The interstices or spaces between the particles of soil are filled with air, or should be, for land plants, but the particles themselves are covered with a thin film of water, and this is all that the root hairs can absorb. If the interspaces are filled with water, the soil is water-logged and the radicle and root hairs cannot breathe, but soon get asphyxiated and perish. The radicle does not absorb water at the tip but some way behind it, and only while the outer walls remain quite thin. The root hairs continue their work for a few days or weeks, then die away and leave no trace behind; but as the radicle lengthens and secondary roots are formed, new root hairs are continually being produced, thus tapping fresh areas for food. In Dicotyledons generally the primary root is permanent, and, if undisturbed, may attain a great size and age in forest trees. From an early stage of growth it commences to give off secondary roots which branch repeatedly, permeating the soil in every direction with their finer ramifications or root fibres. In

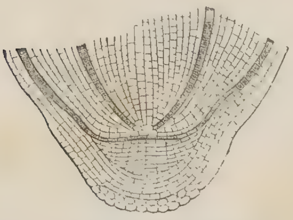


Fig. 12.—Section through the Root Tip of Pentstemon. The bowl-shaped mass at the tip is the root cap; × 60.

Fig. 13.—1, Seedling with the long absorptive cells of its root ("Root Hairs") with sand attached. 2, The same seedling: the sand removed by washing

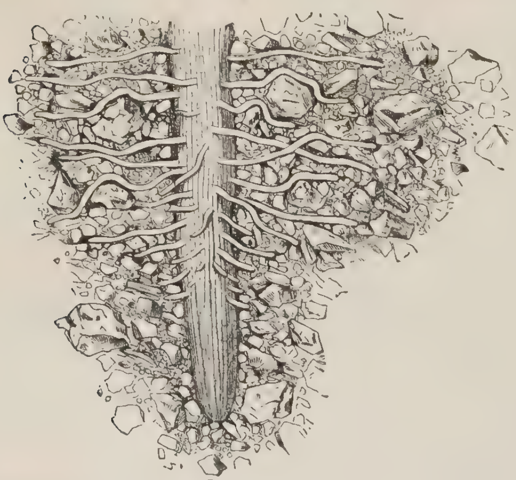


Fig. 14.—Root Tip of Pentstemon with Root Hairs penetrating between the particles of soil; ×10

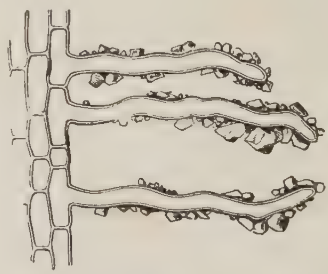


Fig. 15.—Root Hairs or Absorptive Cells of Pentstemon with adherent particles of earth

Monocotyledons, like Lilies, Daffodils, Onions, Palms, and Grasses, the primary root soon ceases to lengthen or dies, but its place is taken by numerous. secondary, and even adventitious, fibrous roots. Some of these attain a considerable thickness in large Palms and Screw Pines (Pandanus), but in grasses they remain slender and fibrous (fig. 16).

Importance of Primary and Fibrous Roots.—In general terms roots serve to fix the plant in the soil. The primary, descending root of forest trees is of considerable importance to many of them, like the Oak, Elm, and Ash, in preventing them from being overturned during gales and hurricanes of wind. To gardeners it is of leading importance in the case of such root crops as Carrots, Parsnips, and Beet. Great care is taken in preparing the soil to a considerable depth, and the seeds are sown where the plants are to grow till they reach maturity. No transplanting is permissible. If the primary root or radicle were broken, a shapely taproot would be impossible. All of them could be transplanted with the greatest facility, and, with care, almost every root would grow, but they would be short, stumpy, forked, misshapen, unsaleable, and useless except for cattle. A deeply worked and well-pulverized soil is necessary to enable the radicle to descend perpendicularly without twisting or bending between stones and hard lumps; and if well manured for some previous crop, the radicle and slender, lateral fibres will be well able to forage for the requirements of a large and shapely root. It is quite different in the case of Cabbages, Apple, Pear, and other fruit trees, because transplanting multiplies the number of fibrous, feeding or absorbing roots. The more fibres upon the roots of Cabbages, Onions, and the like, the sooner they get established in their permanent positions when transplanted. Taproots are undesirable in fruit trees, because they often get down into uncongenial subsoils, while plenty of fibrous roots near the surface induces early fruitfulness and permits of feeding.

Fig. 16.—Meadow Grass—Fibrous Root

Relation of Soil to Roots.—As already observed above, the root hairs of plants apply themselves very closely to the particles of soil, in order to absorb the thin film of water adhering to them. This film contains plant food in a state of solution, and in greater quantity than in the root hairs themselves, but at the same time the solution is very dilute and the root hairs have to absorb a much greater quantity of water than is actually required by the plant in order to get a sufficiency of food. The nature of a soil bears a definite relation to its fertility. A sandy soil, being made up of relatively large particles, can hold only a very limited quantity of water, because the spaces between the particles are large and filled with air. If manure is applied it rapidly decays and much of the plant food in it is washed away into the drainage by rain. If liquid manure is applied, most of it runs away. On the other hand, the particles of a clay soil are much finer, hold more water and plant food, either in solid or

liquid form. If some of the latter is poured on a clay soil, it can abstract ammonia, free potash, phosphoric acid, and various salts containing plant food and hold them till they are absorbed by plants. All clay soils, if not originally fertile, can readily be made so by artificial means, and it only remains for the cultivator to make them sufficiently porous by good tilth to enable the roots of cultivated plants to penetrate freely and collect the food stored.

Water and Air Roots.—While the roots of land plants can only absorb the film of water adhering to the particles of soil, the roots of water plants are able to absorb the free water with which they are surrounded. They are greatly elongated, much more branched than those of a land plant, and thin-walled, without cuticle or root hairs on their surface. A land plant may produce water roots, as when Hyacinths are grown in glasses of water. Another good instance in nature may often be seen where the roots of trees penetrate tile drains and actually choke them up. If the roots of a land plant are immersed in a vessel of water they continue to absorb water for a time, but soon develop true water roots and the earlier or original fibres die. They get their food and air dissolved in the water surrounding them. One peculiar form of air root may be seen in Orchids. The root is surrounded by a membrane of cells, several layers deep, more or less thickened, perforated with holes, and filled with air. They absorb rain containing plant food in solution, and deposited at first in the form of dust on or near the root. If such roots develop on the outside of a flower pot or basket they must not afterwards be buried either in soil or Sphagnum. The writer has seen a fine batch of Moth Orchids (Phalænopsis) killed by placing the small baskets inside larger ones and filling the space between with Sphagnum. In many Aroids that produce aerial roots the surface is loose and spongy and more or less densely covered with root hairs which absorb moisture from the air.

Fig. 17.—Dahlia—Tuberous Root

Tuberous Roots.—The primary and secondary roots of the Dahlia become greatly swollen and spindle-shaped (fig. 17). The thickened portion is intended for the storage of reserve material with which to make a good start the following season in the production of the flower stem. The material stored is inulin. The base of the stem and the upper part of the root of the Turnip becomes greatly thickened and tuber-like, storing starch for the requirements of the flower stem in the second season. In the case of the fleshy, thickened taproots already mentioned, the Carrot and Parsnip store starch for the same purpose as the Turnip, and, all being good for food, they are cultivated for this special purpose by man. The same applies to Beet, which stores a sugar very like cane sugar.

Work of the Roots.—In summarizing the above remarks it may be said that roots fix the plant in the soil, commence to absorb watery solutions of plant food at a very early stage; they breathe, and, in the case of land plants, must be grown in well-drained soils, while they are modified in certain plants to perform similar functions in water, or air, and have become fleshy and constitute a storehouse of reserve food in the cases mentioned. Some substances of plant food are soluble in pure water; others are rendered soluble by the presence of carbon dioxide, lime, and other ingredients in the soil. The root hairs and the younger slender fibres of the root are able to dissolve other substances. Their cell walls are actually permeated with acid sap, and this dissolves substances with which they come in close contact. If a small slab of polished marble is placed in the bottom of a flower pot in which a Sunflower, Broad Bean, or Scarlet Runner is grown during the season, and examined in autumn, it will be found that the roots have left their exact impression by eating away the polished surface. If the ingredients of plant food absorbed were to remain unchanged inside the root hairs the sap would soon be of the same density as the watery solution outside the membranous wall, and the inward current would cease; but their chemical nature is continually being changed in one or other part of the plant, and the cells abutting on those having the root hairs absorb the food from the latter, and so on in succession, until it is carried into the vascular tissue of the root, and thence into the stem. This absorption goes on continually night and day, so long as the conditions are favourable. The result is that a current of sap is being pushed into the interior of the plant by the activity of the roots, and is known as "root pressure", some of the effects of which will be discussed in the chapters on the stem and the leaf. Energy is required by the roots in order to perform all this work, and that is obtained by the absorption of oxygen from the air in the process of breathing. For this reason alone, trees and shrubs should not be planted too deeply, nor should soil be heaped over the surface, where such are already established. We have frequent evidence of large trees being killed outright in a few weeks by the deposition of 3 to 5 ft. of muddy soil or clay over their roots, which cannot breathe nor perform any other function for want of air. Badly drained soils have similarly evil effects. When the soil in flower pots is over-watered, or the drainage hole gets stopped up by worms, the roots cannot get sufficient air, and their functions become deranged, or they die.

The Food absorbed by Roots.—Of the ten elements of plant food that are absolutely essential, all of them, except carbon and a small quantity of nitrogen, are absorbed by the roots. They are oxygen (the free oxygen of the air is used only in breathing), hydrogen, nitrogen, sulphur, phosphorus, potash, calcium, magnesium, and iron. They are not absorbed in this simple form, but in various combinations termed salts (such as nitrates), acids, &c. Oxygen and hydrogen are absorbed in the form of water; nitrogen in the form of ammonia and nitrates; sulphur as sulphates; phosphorus as phosphates; potash and lime in combination with sulphur,

phosphorus, nitrates, &c.; and iron in a variety of compounds. Most of the above are present in sufficient quantity in soils generally, and when land requires manuring, nitrogen, phosphorus, and potash are usually most deficient. Lime is occasionally deficient, and is useful for a variety of purposes. Except in the case of Leguminous crops, such as Peas, Broad Beans, Dwarf Beans, and Scarlet Runners, nitrogen is always necessary unless the soil is very fertile. Leguminous plants have bacteria in small nodules upon their roots, and these bacteria are capable of fixing the free nitrogen of the air. Farmyard manures are very valuable in light soils by increasing their power of holding water, independently of the plant food they contain.

Contractile Roots.—Apart from the functions already described, a large number of bulbous plants are provided with roots which have the

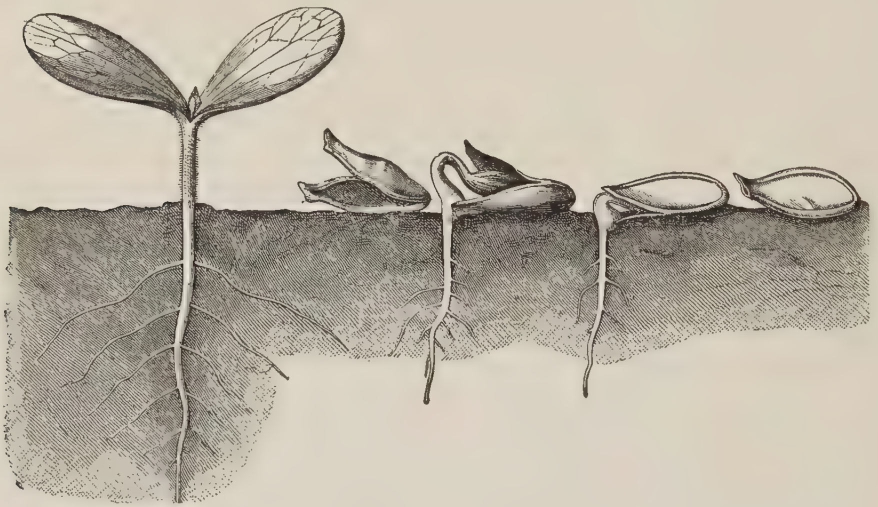


Fig. 18.—Seedling Plant of Gourd (*Cucurbito Pepo*) with Radicle, Caulicle, and opposite Cotyledons. Liberation of the Cotyledons from the cavity of the Seed or Fruit Husk, showing in the central figures the little peg or radicle that serves to fix the seedling.

power of contracting at certain periods, and thus pull down the bulbs or corms deeper into the soil. These roots are known as "contractile". They are generally thicker and fleshier than the more fibrous feeding roots, and are recognized by the transverse wrinkles or rings upon them. The young or new corms of Gladiolus and Crocus, and the young bulbs of many Liliums and other bulbous plants, are all provided with such roots. In the case of seedlings, Dr. Scott says, in his *Structural Botany*, that the young bulb "is gradually drawn down year by year owing to the shortening of the adventitious roots. As the end of the root attaches itself firmly to the soil, the effect of the contraction is to exert a downward pull on the bulb. The upper part of the root is alone capable of contraction, and is much thicker than the rest. The inner cortex is the actively contractile tissue; as it contracts, the external layers are thrown into transverse wrinkles.

New roots of this kind are formed each year, until the bulb has reached its normal depth." [J. F.]

§5. THE STEM AND ITS FUNCTIONS

The Seedling Stem.—Almost any seedling will serve to show the origin and development of the stem from an early stage of its growth.

Fig. 19.—1, 2, Seedling of Nasturtium (*Tropæolum majus*). 3, 4, Seedling of Water Chestnut (*Trapa natans*) with section of seed. 5, 6, Seedling of Austrian Oak (*Quercus austriaca*). 7, 8, 9, 10, Stages in the germination and growth of Date Palm (*Phœnix dactylifera*) with sections. 11, 12, 13, Seed and germination of same of Reed Mace (*Typha Shuttleworthi*). 14, 15, Seedling of Sedge (*Carex vulgaris*). 1–8 nat. size; 9, 10, × 8; 11–13, × 4; 14, 15, × 6.

It forms part of the embryo, while still in the seed. A Stock, China Aster, Cabbage, or Gourd seedling (fig. 18) will serve the purpose. Between the ground and the seed leaves the short, upright portion is the first visible part of the stem, to which various names have been given, including

caulicle, which means little stem. Structurally it is made up of cells, fibres, and vessels, built up in the form of tissue characteristic of a stem. Its functions are to hold up the seed leaves to the light and supply them with water and food materials. Between the seed leaves the first bud of the plant, known as the *plumule,* will be noticed. It is really the apex of the young stem, covered with the rudiments of the first true or rough leaves. Many variations are met with amongst seedlings. For instance, in the Scarlet Runner, Broad Bean, and Oak the seed leaves remain in the seed, below-ground, during and after germination. In these cases the caulicle remains very short, the seed leaves do not make their appearance, and the plumule is the first part to rise above ground. The caulicle undergoes modification in other ways in certain plants. The upper portion of the tuberous swelling of the Turnip and Radish consists of the caulicle, enlarged and fleshy, to serve as a store for reserve food.

The Growth and Thickening of the Stem.—As the plumule grows and develops into a stem of some length in the Stock or China Aster, it is seen to be self-supporting, because the thickness and woody matter in the interior is proportionate to the height. The leaves of the Cabbage are much larger, and the stem becomes greatly thickened to support them. The stem of the Gourd becomes enormously lengthened in proportion to its thickness, but has to lie on the ground unless supported. If the stem of any of these plants is cut across it will be found to have a core of pith, consisting of thin-walled cells, surrounded by a layer of wood of greater or less thickness, and that again by a bark of no great thickness, and covered on the outside with a skin or epidermis. Such stems of the first year are usually green, because they contain chlorophyll, and are capable of manufacturing plant food. The skin of green stems also has air pores, or *stomata,* such as leaves have, and takes in oxygen from the atmosphere for the purpose of breathing. The above, in general terms, is the structure of a stem of one season's growth.

In order fully to understand the thickening of a stem it will be necessary to consider the structure of a shrub or tree, say the stem of an Apple tree of some size. If the stem is cut across, the pith (fig. 20) will be found in the centre, and probably of small size, owing to the pressure of wood upon it. This is surrounded by a number of layers of wood, each ring corresponding to one year's growth, and thus the age of the tree may be determined. This wood is made up of cells, wood fibres, and vessels more or less thickened internally. Surrounding the wood in winter is a thin layer of thin-walled cells, termed the *cambium* (No. 8), to be considered presently. Outside of the cambium is a ring or rind forming the bark, now of considerable thickness by comparison with that of a Stock or Gourd. It has lost its skin or epidermis (No. 1), and in place of the stomata, openings loosely filled with cork cells, and known as *lenticels,* may often be observed on stems or branches not too old. These are breathing pores. A large portion of the bark is made up of corky tissue (No. 2), gradually breaking away from year to year, while the inner

portion is younger and more fibrous. Collectively the various members of the rind are known as bark. Some of the fibres are thickened, and known as hard bast (No. 5), while the inner cells remain thin-walled, constituting the soft bast (No. 6). Archangel mats are made from the hard bast of the younger portion of the bark of the Lime tree. Sieve tubes (No. 7) are included in the hard bast, which serves to give toughness and pliability to stems and branches. The bark, collectively, also serves to protect the cambium from injury and the wood from decay; hence one good reason for careful pruning and judicious lopping of all trees whatever.

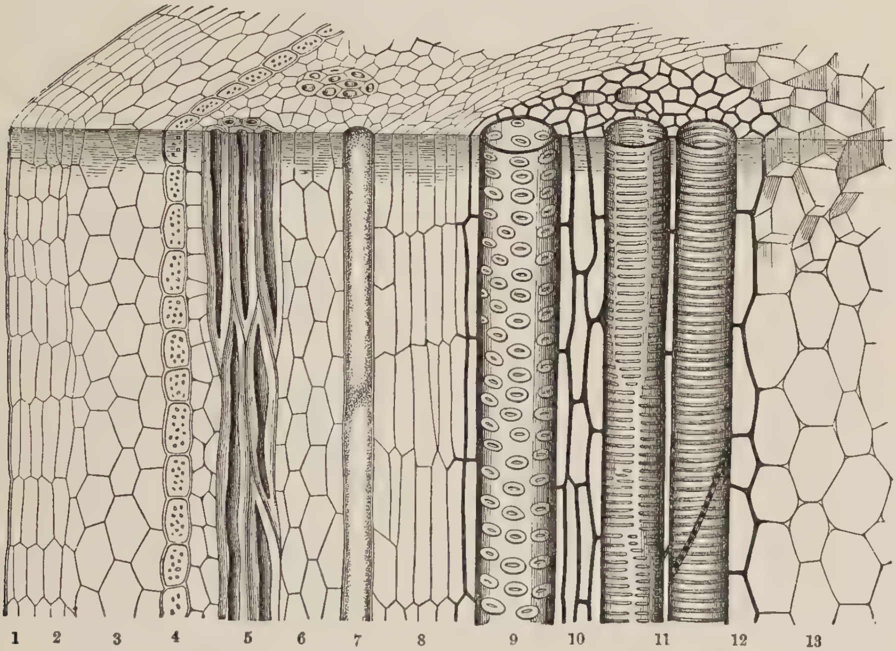


Fig. 20.—Portion cut from a Branch of a Leafy Tree × about 200 (diagrammatic)

1, Superficial coat (Epidermis). 2, Cork (Periderm). 3, Cortical parenchyma. 4, Vascular bundle sheath. 5, Hard bast. 6, Soft bast. 7, Sieve tubes. 8, Cambium. 9, Pitted vessel. 10, Wood parenchyma. 11, Scalariform vessels. 12, Medullary sheath. 13, Medulla or pith.

The Cambium.—Even in winter, when the trees are leafless and comparatively at rest, the thin-walled cells of the cambium are small and filled with protoplasm; it really constitutes the only live portion of the tree at this period. It forms a thin, cylindrical jacket to the trunk of the tree, and gradually tapering cylinders to each branch and twig, till continuous with the small core in each live bud on the tree. The cambium descends to the roots in like manner. When the temperature rises in spring the cells are excited into rapid growth, and, with abundant supplies of stored food close to hand, they soon reach full size, divide, grow, and multiply rapidly. The cells on the inner side develop new fibro-vascular bundles, side by side, in a continuous ring all round last year's wood. Those on the outside of the cambium form new hard and soft bast. Thus the wood increases in

thickness by the deposit of a new ring on the outside of its mass, while the bark thickens by the deposit of a new ring on the inside of last year's one.

The existence of the cambium explains the art of budding a Rose, grafting a scion or shoot of one Apple tree on to another, inarching a young Vine on the rod of an old one, and the grafting of shoots of a Clematis, Tree Pæony, and Wistaria on to the roots of another for the purpose of increasing their numbers. The object in each case is to get the only live portion of the scion of the tree, shrub, or climber into contact with the cambium of the stem and root, respectively, used as stocks. The cambium of the one coalesces or joins with that of the other, and forms a new layer of wood over the old. If the grafted portion of an Apple or other tree were examined after one hundred years, the old cut surfaces would still be present, for mature or ripened wood, being dead, never unites. The whole of the wood of a tree, after it is fully ripened, is dead, though it may exist for one thousand years or more, protected by the bark, and be of service to the tree.

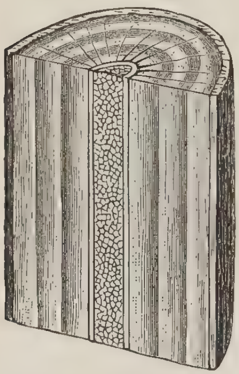


Fig. 21.—Section of Dicotyledonous Stem, showing central pith, three zones of wood, and bark on the outside (diagrammatic)

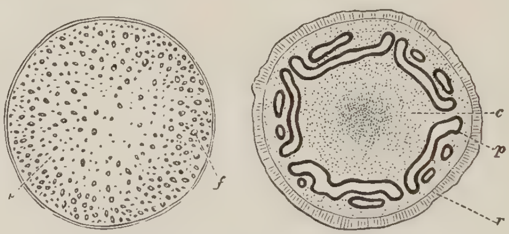


Fig. 22.—Section of Stem of Palm and Fern

Dicotyledonous and Monocotyledonous Stems.—The above descriptions relating to the thickening of stems and the cambium layer apply entirely to Dicotyledons. The structure of a three-year-old stem is represented by fig. 21. Trees and shrubs are less numerous amongst Monocotyledons, whilst herbaceous types in cultivation are very numerous. Structurally they are all much alike, whether herbs, shrubs, or trees, of one or many years' duration. Palms, some species of Pandanus, and a few Bamboos are the only plants of tree-like habit or dimensions in the class. The stem of a Palm may be taken to consider details of structure (fig. 22). There is no pith in the centre, nor bark on the outside. There is a skin on the epidermis, and that is permanent. The body of the tree is made up of short-celled ground tissue, and distributed through this are very numerous strands or bundles of fibro-vascular tissue. They are isolated in the ground tissue, and when the cells, fibres, and vessels of which they are composed have reached their full size, and thickened their walls, they can make no further growth, as there is no cambium. Towards the circumference of the stem the fibro-vascular bundles are the most numerous, and

as the cells of the ground tissue in that region thicken their walls greatly, it follows that the outside of the stem of a Palm is very hard. A seedling remains without a stem till the leaves have attained a large size and a certain number, when the stem rises up almost of the same thickness throughout. As Palms generally do not branch or increase the number of their leaves, the thickening of the stem is unnecessary. Some species of Dracæna thicken their stems slightly by some of the cells of the outside of the ground tissue retaining the power of dividing and forming new tissue like the rest. The stem of a Fern consists of ground tissue, with an interrupted ring of woody tissue in the form of curved plates and isolated pieces (fig. 22). In all these cases strands of fibro-vascular bundles pass from the wood of the stem or branches into the leaves.

Fig. 23.—Lily—Scaly Bulb. Onion—Tunicated Bulb

The functions of the stems and branches of all the above plants are to support the leaves, so that they may be properly spread out to the light, and to convey water and food to the leaves, flowers, and fruits. As the stems of trees must be strong to bear the weight of branches and leaves, so they develop a much larger proportion of woody tissue than herbaceous plants require to do.

Bulbs, Corms, Tubers, and Rhizomes.—A *bulb* is really a very much enlarged bud, consisting for the most part of leaves, with a very short and thin flat stem. Lilies have scaly bulbs (fig. 23), while Hyacinths, Tulips, Daffodils, and Onions (fig. 23) have tunicated bulbs, so called because the sheaths are continuous all round, like a tunic. If the sheaths or scales are pulled off one by one there will remain a thin, solid part, which is the stem. The Tiger Lily, and several others, bear *bulbils*, or small bulbs in the axils of their leaves, and their structure is similar to the parent bulb. The bulbils form a ready means of propagating the plant (fig. 24).

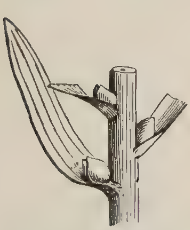


Fig. 24.—Bulb-bearing Lily—Portion of Stem

Fig. 25.—Colchicum—Corm

Corms are produced by the Crocus, Gladiolus, Colchicum (fig. 25) and others. They consist of a short, flattened stem, covered with dry, scale-like sheaths, or modified leaves, and surmounted by a tuft of perfectly developed green leaves. They root from the base. They produce a new corm, or several, on the top of the old one every year, the old one dying.

Small ones are produced at the base of the Gladiolus corm and serve for propagation.

A *tuber* is a short, not flattened, but fleshy stem, growing a little at the apex and dying a little at the base every year. Roots are given off from the sides, as in the Arum Lily and Caladium. The tuber of the Potato is the thickened and fleshy end of an underground branch, which develops into a new plant, the stem of which bears the roots, while the old tuber dies. The Potato stores starch, while the tuber of the Jerusalem Artichoke stores inulin, and both are cultivated for these reasons, being useful for food. The tuber of the Jerusalem Artichoke is of similar origin or structure to that of the Potato.

Rhizomes are creeping, underground stems, giving off roots below and leaves and flower stems at the end of the main axis or side branches.

Fig. 26.—Rhizome of Iris

Fig. 27.—Rhizome of Sedge (Carex)

Examples of stout rhizomes are those of Solomon's Seal and many of the Irises (fig. 26). Slender rhizomes are produced by Couch Grass, Sedges (fig. 27), Lily of the Valley, and many others. The stem nature of these rhizomes may often be testified by the presence of very much reduced scale-like leaves, as in the cultivated Spearmint and Peppermint.

The object of bulbs, corms, and tubers is to store food with which to commence growth, flower, and fruit in the following year. Rhizomes serve a similar purpose as well as to increase the plant and extend it into fresh ground. Mints are noteworthy in this respect. All of these types are of easy propagation by offsets and divisions in gardens. By virtue of the stored food in their bulbs Hyacinths, Tulips, Daffodils, Snowdrops, and others may be grown in the dark till their flowers are visible, when they must be placed in the light for the benefit of the young leaves. The Hyacinths and Daffodils may be, and are, grown entirely in clean water till they have finished flowering, solely as a result of the starch stored in the leaves and fleshy stems constituting the bulbs. They require to be grown in good soil for some years afterwards in order to recuperate before they can flower as well again.

Besides such modified stem structures as corms, tubers, and rhizomes

A DUTCH TULIP FARM

(5) DOUBLE TULIPS GROWING AT WISBECH, CAMBRIDGESHIRE (Mr. J. W. Cross)

DUTCH AND ENGLISH TULIP FARMS

there are many plants in which the stems have assumed the form of leaves. One of the best-known examples is the Common Butcher's Broom

Fig. 28.—Plants with Leaf-like Branches

1, Young shoot of *Ruscus Hypoglossum*. 2, The same branch fully grown with flowers on the cladodes. 3, Young shoot of *Ruscus aculeatus*. 4, The same branch with flowers on the cladodes.

(*Ruscus aculeatus*); others are *Ruscus Hypoglossum* (fig. 28) and the Alexandrian Laurel (*Danæa Laurus* or *Ruscus racemosus*). These plants, being apparently unable to develop true leaves, have modified some of their

shoots for the purpose of assimilation. These shoots are flat and leaf-like, but it will be noticed that they bear flowers near the centre, a thing no true leaf does. It will also be noticed that instead of spreading out horizontally these peculiar shoots (known botanically as *cladodes* or *phyllo-clades*) are set more or less vertically. Other plants with modified structures are to be found in such genera as Asparagus, Acacia, Eucalyptus, Grevillea, Phyllanthus, Phyllocactus, Phyllocladus, Semele, &c. [J. F.]

§ 6. LEAVES AND THEIR WORK

Seed Leaves and True Leaves.—The first leaves of a plant are those formed in the seed, and which may or may not rise above-ground during germination. Those of the Cabbage, Mustard (fig. 13), Gourd (fig. 18), Beech, and Onion rise above-ground and become green. As soon as this has taken place the seedling has started life on its own account, manufacturing its own food in the green seed leaves and stem. The seed leaves of many plants become fleshy, store food while in the growing seed, and never rise above-ground during or after germination, but supply food to the seedling till able to forage for itself. Examples of this may be seen in the garden Pea, Sweet Pea, Broad Bean, Scarlet Runner, Horse-chestnut, and Oak (fig. 19, p. 35). The seed leaves differ more or less widely in form from the true leaves that follow. All of the plants mentioned in this paragraph, except one, have two seed leaves or cotyledons and belong to the class Dicotyledons. The Onion, Lily, and others have only one cotyledon, and are Monocotyledons. The seed leaves of Iris and grasses never rise above-ground, and as they have only one each they belong to the latter class.

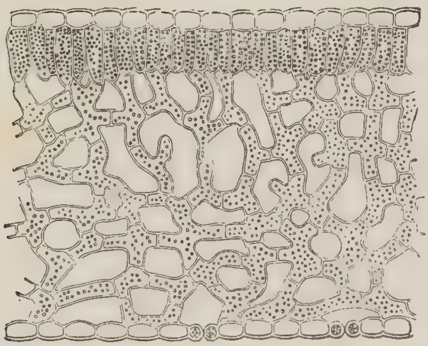


Fig. 29.—Vertical section through Leaf of *Franciscea eximia*, showing Epidermal, Palisade, and Spong Tissue, and two stomata cut through

The true or rough leaves are those that follow the seed leaves in succession, increasing in size and varying in form with each individual till the plant reaches the adult state. The leaves, taken altogether, constitute the foliage of the plant.

Structure and Contents of a Leaf.—The naked-eye characters of a leaf may be seen in that of a Vine. The leaf is three- to five-lobed, with as many primary veins running from the base to the tip of each lobe. Smaller veins pass through the leaf in a variety of directions, the smaller ones forming a kind of netting. The veins are fibro-vascular tissue that come from the stem, pass through the leaf stalk, and divide

into three or five main branches at the base of the blade. The spaces between the veins are occupied by thin-walled cells of various forms according to their function. A section through a part of this kind of tissue in Franciscea (or Brunfelsia) is shown in fig. 29. The layer of empty cells on the upper side is the skin or epidermis, the cells of which are filled with water in the live state. The outer walls on the exposed surface are more or less thickened, the thickening being termed the cuticle. In leathery leaves, like those of a Camellia, Palm, Laurel-cherry, or Rhododendron, the cuticle is considerably thickened to keep out water and to prevent the loss of it from within. In many leaves the interior (fig. 31) of the wall is greatly

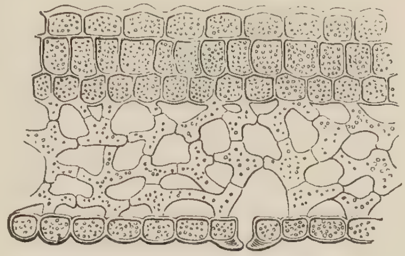


Fig. 30.—Vertical section through a Leaf, showing Epidermis, Palisade, Spongy Tissue, and a Stoma cut through

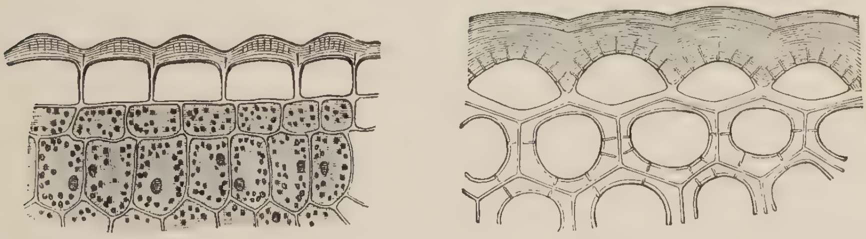


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Fig. 31.—1, Shows Epiderm with thickened upper wall and palisade cells beneath, filled with chlorophyll. 2, Epidermal Cells thickened on one side, with Cellular Tissue beneath.

thickened to impart strength and protection to the softer tissues. Below the skin are *palisade* cells, placed at right angles to the surface and one, two, or more layers deep. These are filled with protoplasm, chlorophyll, starch, sugar, and sometimes other substances. Between the palisade cells and lower epidermis lies a mass of spongy tissue not always so open as in this particular leaf, but filled more or less with similar materials to the palisade cells. The lower skin shows two air pores or *stomata* cut through and leading into breathing or respiratory cavities. The latter are continuous with others leading all through the leaf. The air pores of land plants are most often situated on the lower surface of the leaf, but may be equally numerous on both sides of the leaves of Iris, Carnation,

Fig. 32.—Stomata

Surface view of a portion of the Frond of a Fern, *Nephrodium Filix-mas.*

and others equally exposed to light on both surfaces. The internal structure in these cases is alike on both sides. The leaves of Water Lilies and others which float on water have the air pores on the upper surface; while leaves developed under water have neither cuticle nor air pores. The tissue of a Mushroom contains neither chlorophyll nor starch.

Work of a Leaf.—The leaves and other green parts of a plant constitute a workshop of many compartments, in which the raw food materials are organized into more or less simple or complex substances for the building up of the various parts of the plant body. The green chlorophyll granules are the agents, under the influence of sunlight, whereby these remarkable chemical changes are brought about. Starch is the first visible product, and first makes its appearance in the form of small grains in the chlorophyll granules. The leaf breathes by absorbing oxygen from the air, and that gives it power or energy by which the other chemical changes are brought about. The oxygen attacks and destroys some of the material in the cells, unites with carbon to form carbon dioxide, which is given off into the air as in the breathing or respiration of animals. The leaf also absorbs carbon dioxide from the air, breaks it up, gives off the oxygen, and the carbon unites with the elements of water brought into the plant by the root. The more complex composition of the protoplasm is effected in the leaf by the addition of the other necessary elements of plant food absorbed by the roots (see p. 33). This process of building up organized matter from the raw materials is termed *assimilation*, and can only be carried on during daylight, though it may possibly be done artificially by electric light. Plants which have no leaves, like the Cacti, assimilate by means of the chlorophyll in their stems and branches.

The effect of light and shade on the leaves of plants is not fully appreciated by all gardeners. Too often we see plants crowded so much together that only a very small percentage of the leaves have any chance of being bathed in sunshine during the day. Fruit growers will have too many trees to the acre, probably thinking that the crops will be weighty in accordance with numbers. The exact reverse is really the case, for the simple reason stated above — that only under the influence of daylight can the starch and other building-up materials be formed in the cells of the leaves. The great bulk of the dry weight of any plant is obtained from the atmosphere, not from the soil; hence the necessity of allowing a fair amount of space between one plant or one tree and another. (See pp. 108, 141.)

Another kind of work carried on by leaves is *transpiration*, or the passing off of watery vapour into the air. The cells bordering the intercellular spaces when gorged with water give off some of it in the form of watery vapour into the cavities communicating with the stomata. During daylight, and when the air is comparatively dry, the stomata open and the watery vapour passes out. The cells bordering the air cavities would soon get dry and flabby, but prevent this by absorbing water from cells behind them, and these in turn from cells more deeply

seated. This is continued through the leaf, its stalk, the branches, stem, and roots until a current of water, known as the "transpiration current", is set up from the roots to the leaves. In the open air and on a windy day this current is often so great that the roots cannot supply it, more especially if the soil is dry, and the leaves flag as a consequence. This phenomenon may often be observed in the case of pot plants if allowed to get dry, whether under glass or outside. It can be remedied by watering the soil in the pots and by syringing the foliage. The undue loss of water from plants under glass can be more effectually prevented by closing the ventilators before syringing, and shading may be resorted to in extreme cases. The atmosphere then becomes saturated, thereby largely checking transpiration for the time being, and the leaves resume their wonted stiffness. This rapid ascent of water serves to keep the plants cool in hot weather, the cells turgid, and also brings in plant food. Transpiration is a vital process regulated by the protoplasm in the leaves and is somewhat different from evaporation pure and simple. For instance, a Stonecrop may be placed between sheets of paper, covered by a board and held down by a weight. It will continue to elongate and even open its flowers under such conditions; but if placed in a basin and some boiling water poured over it to kill it the stems and leaves will part with their moisture in a few days. At night the stomata close, and transpiration ceases. Another phenomenon may often be observed in the morning. Drops of water may be seen on the tips of the leaves of Aspidistras, Arum Lilies, Fuchsias, Chinese Primulas, and many others as a result of root pressure. Over the ends of the vascular bundles of the leaves of those plants water pores are situated, and unlike stomata they never close. The roots continue to absorb water night and day, and when transpiration ceases the cell walls become saturated. Water then filters into the cavities of the wood fibres and vessels under pressure from the roots until it reaches the water pores, where it escapes from the overgorged tissues.

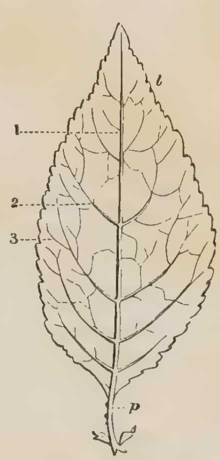


Fig. 33.—Simple Leaf

p, Petiole, with Stipules at the base; 1, midrib; 2, 3, branches of the midrib.

Forms of Leaves and their Clothing.—Seed leaves are always simple or in one piece, though they are lobed in a few cases. Simple leaves (fig. 33) are represented by those of the Cherry, Apple, Fuchsia, and Camellia. They may be more or less deeply and *palmately* lobed, as in the Vine, Ivy, Sycamore, Plane, and Hop. The lobing may be in the form of a feather, as in the common Polypody, Marguerite, Oak, and Water-cress. This form is termed *pinnatifid.* The cutting is carried still deeper in Celery, Parsnip, and Carrot, and the simple leaf termed *pinnatisect,* or it may be twice pinnatisect in the Carrot. Leaves are "compound" when each separate piece into which they are divided is jointed, as in the Laburnum (fig. 34), the Virginia Creeper, Horse-chest-

nut (fig. 35), and Aralia Veitchi. The latter three have *palmate* leaves. The feathered type of compound leaves is termed *unequally pinnate* in the Rose, Robinia (fig. 36), Ash, Elder, and Walnut. The Laburnum and Clover have ternate leaves, because cut up into three jointed leaflets. The forms of leaves are practically endless, and should be studied from the textbooks.

Fig. 34.—Seedling with opposite Cotyledons and alternate Foliage Leaves (*Cytisus Laburnum*)

The surface of leaves may be smooth or glabrous, that is, without hairs, or they may be covered with hairs varying greatly in density, length, or form. Hairs that lie smooth and close are *silky*; those that are interwoven with one another are felted or *tomentose* (fig. 37); long and loose ones may make the leaves *shaggy* or *woolly.* Amongst the hairs on the leaves of the Nettle some have a swollen base and are stinging. Those of the Stock are branched in a starry fashion and are termed *stellate.* To this class belong the hairs on Draba (fig. 37), while this is carried further in Elæagnus and other shrubs, the branches of the hairs being united in the form of circular scales, like a Japanese parasol in miniature, with a very short stalk. The hairs are useful in a variety of ways, by running the moisture off the plants, by preserving the liquids in the leaves of plants that live in dry places; while the hairs and bristles on many Cacti serve to keep them cool under the influence of a scorching sun in desert regions.

Fig. 35.—Horse-chestnut—Compound Palmate Leaf

Fig 36.—Robinia—Compound Unequally Pinnate Leaf

Arrangement of Leaves.—They are opposite or in pairs in the Carnation and Sweet William; in whorls of three in the Oleander, and in whorls of four, six, eight, or a higher number in species of Bedstraw. They are alternate in the Lime, Beech, Elm, and others, where the third leaf comes in a line with the first, counting upwards or downwards. They are spirally arranged on the shoots. This also applies

to the Apple, where the sixth leaf comes above the first, after the spiral has passed twice round the shoots. This means that the leaves are separated from one another at an angle of two-fifths the circumference

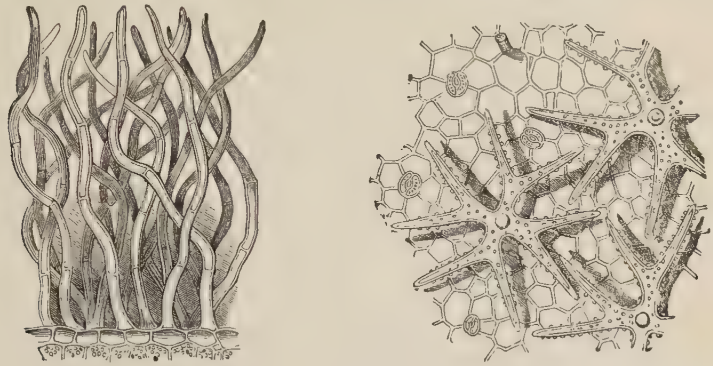


Fig. 37.—1, Felted Hairs on Leaf of Edelweiss. 2, Stellate Hairs on the Epiderm of Draba.

of the stem. These arrangements are intended to distribute the leaves so that all will get a due share of light. This is well shown in the Elm (fig. 38) and the Ivy (fig. 39).

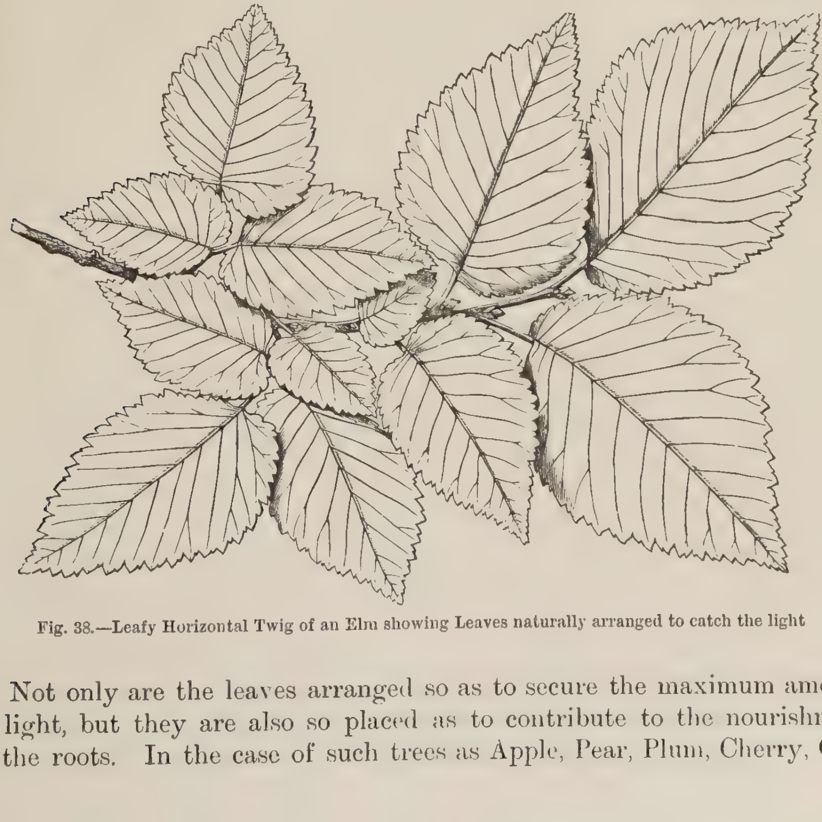


Fig. 38.—Leafy Horizontal Twig of an Elm showing Leaves naturally arranged to catch the light

Not only are the leaves arranged so as to secure the maximum amount of light, but they are also so placed as to contribute to the nourishment of the roots. In the case of such trees as Apple, Pear, Plum, Cherry, Oak,

Chestnut, Beech, Elm, Lime, Ash, &c., the leaves are arranged over each other like tiles or slates on a roof to throw the water from the centre to the outside. In this way the rain trickles from one leaf to another, and the great bulk of it falls around the circumference. It is just at this place that nearly all the fibrous feeding roots of such trees exist. Consequently, when the rain falls they get the first supplies, and are thus refreshed and enabled to take up more food from the earth in solution.

In the case of the Yew and many Coniferous trees and shrubs the rain is thrown inwards as well as outwards, owing to the way in which the leaves and branches are arranged.

In the case of other plants, e.g. the Caladium (fig. 40), it will be noticed that the leaves are so arranged that water is thrown to the circumference

Fig. 39.—Ivy on the ground showing normal arrangement of Leaves to catch the light

or periphery of the plant, to which the fibrous roots extend from the tubers. On the other hand, in the case of the Rhubarb (fig. 40) the large leaves directed upwards naturally collect the rain and direct it towards the centre of the plant, and thus down to the thickened rootstock, the fibres from which do not extend horizontally. The leaves of Turnips, Radishes, Beetroot, Parsnips, Carrots, Dandelions, Chicory, &c., and most bulbous plants are arranged in a similar way, to conduct water inwards for the benefit of their rootstocks.

Modified Leaves.—The scales on the bulb of a Lily are modified by being fleshy, without chlorophyll, and filled with starch. Those of the Daffodil and Onion are made up of the sheathing bases of leaves, and go right round the bulb. The Onion stores a glucose-like substance or grape sugar in the sheaths of the bulb. The stored materials enable the plants to make a good start into growth the following year, and to throw up their flower stems. In late summer and autumn the apex of each shoot and twig of most trees is covered with brown scale-like leaves for the purpose of protection. The flowers of the Peach, Horse-chestnut, and Rhododendron are covered in the same way during the winter. The scales are

simply ordinary leaves arrested at an early stage of growth, and have the same arrangement as they. At the base of the individual flower stalks in many plants are small leaves, termed *bracts*; in the Carnation they come close up to the base of the calyx in two pairs. The bracts are very numerous in the Marguerite, Cineraria, and other composites, and closely surround each flower head, like overlapping scales. The bracts surrounding the clusters of flowers of the Poinsettia are large and highly coloured.

Fig. 40.—Transmission of Water by Leaves towards circumference in (1) Calladium, and towards centre in (2) Rhubarb

The leaves of some plants, like the Sarracenia (fig. 41), Darlingtonia (fig. 41), Nepenthes or Pitcher Plant (fig. 41), and *Heliamphora nutans* undergo complete changes in appearance for special purposes, chiefly for the purposes of catching insects and afterwards digesting and absorbing them. In the case of the Sarracenia, Darlingtonia, and Heliamphora the leaves roll themselves into a tube or trumpet, on the inner surface of which a honey-like substance is secreted, and on which numerous sharp, bayonet-like hairs point downwards. The insects, being attracted by the honey, enter and feed till satisfied, but when they attempt to get out they are repulsed by the bayonet-like hairs, and eventually sink back exhausted and die.

In the case of the Pitcher Plant (Nepenthes) the leaves are normal flat expansions for a considerable length. The tissue on each side of the midrib

Fig. 41.—Pitcher Plants

1, *Sarracenia variolaris*. 2, *Darlingtonia californica*. 3, *Sarracenia laciniata*. 4, *Nepenthes villosa*, reduced to one-half natural size.

suddenly ceases to grow, and the midrib develops by itself for several inches. Eventually, however, a pouch-like organ or "pitcher" is formed

at the tip, and is provided with a lid. This soon opens and allows the ingress of various insects, which ultimately meet the same fate as those entering the other plants referred to. In fig. 41 (4) the stout downward-pointing teeth around the rim of the pitcher are shown.

Another plant with similar contrivances of modified leaves is the Australian Pitcher Plant (*Cephalotus follicularis*), (fig. 42).

Fig. 42.—*Cephalotus follicularis*

The Fall of the Leaf.—From the earliest development of the leaf in spring, preparations are being made at the base of its stalk, whereby it will be thrown off in autumn in the case of deciduous trees and shrubs. This is brought about by the development of a layer of cork cells right across the stalk, exclusive of the vascular bundles. During the autumn, but especially in October and November, this layer of cork becomes completed by the maturing and dying of the cells, and it needs only a breeze of wind or a night's frost to snap the vascular bundles and bring the leaves down in showers. The leaves of the Ash are still quite green when this happens. This state of maturity in the leaves of the Peach is favoured by giving abundant ventilation both at the top and bottom of the house in the case of planted trees. Those in pots should be stood outside after the fruit is gathered. Pot Vines may be served in the same way. Established Vines that are tardy in dropping their leaves may be assisted to mature them by an abundant ventilation, with a dry atmosphere, and a gentle heat from the hot-water pipes. It would be unwise to hasten the process unduly by keeping them very dry at the roots.

[J. F.]

§ 7. MOVEMENTS OF WATER AND FOOD PRODUCTS IN PLANTS

Root Pressure.—Having considered the mechanism and some of the properties and contents of roots, stems, and leaves, the way is now clear to discuss some of the phenomena exhibited by plants as a whole or in a connected way. There is no regular circulation of sap in plants comparable to the blood in animals, nor a constant flow in any one direction, except temporarily. The flow is in many and diverse directions, according to the particular kind of work being conducted and the part of the plant where it is taking place. The movement is a progressive, not a circulating one. Root pressure, taken on the whole, is the most constant or continuous force at work in causing a rise of watery fluid in the plant. The pressure it exerts may be most readily observed in spring, when all the tissues of deciduous trees and shrubs are gorged with water, prior to the expansion of the leaves. The Vine exhibits this pressure in a marked degree, and though it varies within limits, according to the size and vigour of the plant, it has been found to support a weight of nearly 15 lb. to the square inch. This alone enables the sap to rise to the apex of the longest rod, because the force of capillary attraction must also be reckoned with when it is remembered that the cavities of the fibres and vessels of the wood get filled with water and air—a combination that is difficult to move. Trees, shrubs, herbaceous plants, and annuals exhibit this root pressure, but in low-growing plants it is most observable at night and early in the morning, that is, some time after transpiration has ceased and before it commences to take effect again with daylight and a drying atmosphere. Root pressure is of great importance to plants that are making their growth, by keeping their tissues gorged and extended with water, without which growth would be impossible. It is equally important to deciduous trees and shrubs, which require a considerable force to expand their winter buds and urge them into fresh growth. Plants grow more rapidly by night than by day, because root pressure is then exerting its full force. Even if this is not sufficient to raise water to the tops of the tallest trees, a considerable pressure is exerted on the buds by the expansion of the air bubbles in the water of the wood cavities as a result of the rise of temperature in spring.

Water of Transpiration.—As above stated, this current is set up by the action of the leaves, and by some has been described as a "transpiratory pull". The effect it has towards the base of the stem is that of "suction". It acts only during the day, and, in the case of deciduous trees, only comes into play when the leaves are expanded and the air pores or stomata are sufficiently developed to commence work. When transpiration has been at work for a time the cavities of the wood fibres and vessels get drained of their liquid contents and filled with air, root pressure is subjected to a negative pressure as a result, and the up current of transpiration is

dominant. When pot plants and those in the ground are well supplied with water, and their leaves do not flag, it is clear that the great volume of water being given off by the leaves must be coming directly from the roots, and that the absorbent activity of the latter is equal to the demand made upon them. It has been calculated that hundreds of pounds of water are given off by the leaves of trees on a hot day (see p. 120). The water of transpiration is the most rapid current of watery fluid known in plants, and is most characteristic of woody plants; it is more feeble in herbaceous plants with a less-developed vascular system; and non-existent in cellular plants. Since the vessels of the wood are filled with air, the water must necessarily travel in the walls of the wood, so that there is a continuous passage or highway for it from the longest or remotest root fibres to the tips of the leaves. In trees, like the Oak, Ash, Lime, Apple, Cherry, and all other Dicotyledons, there is one main current through the trunk. This flow is chiefly through the younger or sap wood, also known as *alburnum*, less feebly through the heart wood or *duramen*, owing to obstructions caused by age. The pith and bark may be removed without causing any diminution in the rise of the sap. In Monocotyledons, like Palms, there is not one main current, but hundreds of small ones in the trunk of a good-sized tree. The transpiration current rises in the small, isolated fibro-vascular bundles distributed through the ground tissue.

In the case of the two great causes of the movements of water in plants just discussed, it must be presumed that the temperature is adequate, since they take place under natural conditions. When Vines, Peaches, Figs, Melons, Cucumbers, and Tomatoes are being forced, out of their natural season, the necessary temperature best suited to each subject must be supplied artificially. Feeding, watering, and the amount of atmospheric moisture have to be controlled likewise by the cultivator, if the best produce is to be secured. Light is liable to be deficient in winter, and full advantage must be taken of it, considering how vital it is to growing plants, from the start till the fruit is matured. This requires properly constructed houses with the glass kept clean. Ventilation, during the middle of the day, at least, is beneficial in promoting transpiration, drying the atmosphere, keeping the functions of the leaves in healthy condition, and hardening the tissues of stems and leaves by the proper thickening of their cell walls, thereby preventing them from becoming unduly "drawn". The houses can be closed early in the afternoon, thereby conserving the sun heat, if any, for that is more favourable to growth than artificial heat. The foliage may be syringed, if the nature of the weather for the time being warrants or requires it; transpiration will be immediately checked and root pressure will soon begin to exercise its powerful effect upon growth, so that no time is lost by giving timely and judicious ventilation.

Transport of Food Materials.—All the food of green plants is manufactured in the leaves and other green parts, and it follows that it must be transported or conveyed to the various points where growth is going on.

When the temporary reserve in leaves consists of starch, it is first converted into liquid sugar or glucose, and can then be conveyed to the growing points of stems and branches, with the young, undeveloped leaves upon them, to flowers, fruits, and seeds. This necessarily means minor currents of slow motion, with usually short distances to travel. Towards the end of the season, when growth is more or less completed, much of the food prepared in the leaves must be carried away and stored in the trunks of trees, in bulbs, corms, tubers, tuberous roots, taproots, and other parts of plants according to the kind. This implies downward currents of water, containing the food materials dissolved in them, and these must also be slow movements. In the case of trees and many other plants it is well known that a considerable number of new roots are made in autumn. This is due to the warmth of the ground and the autumn rains, as well as to the existence of a plentiful supply of ready-made food. The rain softens the previously dry and hard earth, and thus enables the roots to penetrate it and extend their system. In trees this food must often travel considerable distances, but rapid transport is favoured by the presence of sieve tubes or continuous vessels in the hard bast, situated in the inner and younger layers of bark. In Palms and other Monocotyledons this hard bast is situated in the isolated fibro-vascular bundles, as there is no bark in these cases. Storage may take place in cells that contain no protoplasm.

Water Plants.—As these contain little (or no) woody matter in their tissues the rise of sap is of a feeble character, but when wholly submerged there is no transpiration current at all. When the roots are in soil, food would be brought in that way, while the oxygen for breathing purposes and the carbon dioxide absorbed by the leaves are taken directly from the surrounding water. The leaves and stems have no cuticle, so that each cell comes in direct contact with water holding food in solution. Floating plants get all their food directly from the water, except the carbon dioxide of the air available to the exposed leaves.

Sap in Winter.—When the leaves fall in autumn, transpiration ceases. Root pressure continues till all the tissues get filled with water and turgid, including the cavities of the wood fibres and vessels, which also contain air. The gradual falling of the temperature also makes the roots less active, though not entirely dormant. A considerable number of plants bloom in winter and require a modicum of water. Evergreen trees, shrubs and herbs, which retain their leaves, must have a certain supply of liquid to keep them turgid and alive. The roots themselves keep extending for an unknown length of time after the fall of the leaf, except when the ground is frozen; and what is used up in these various ways must be made good by the absorbent hairs and superficial cells of the younger roots. It is natural and necessary that the roots of plants belonging to temperate climates should have an adequate supply of water even in winter. This explains bud-dropping in Peaches that have been allowed to get over dry at the roots in winter till the buds perish, as the extremities of the trees

are the first to suffer. Then when growth recommences in spring the dead buds are thrown off, if not before. Camellias suffer in the same way, in conjunction with fluctuations of temperature. If a period of dry weather succeeds the transplanting of Hollies, Laurel-cherries, Conifers, and other evergreen subjects in winter they often get killed, thus proving that the leaves give off more water from their surfaces than the mutilated roots can supply.

Bleeding.—If a Vine rod is cut into the wood in spring, before the expansion of the leaves, it will bleed strongly for many days, and may even die or become so weak as to be useless. Its tissues are gorged with watery fluid containing a considerable amount of liquid plant food, dissolved by the water from cells where it was stored. Root pressure is very strong at this period, and the vessels of the wood of the Vine are very large. Much of the stored food is thus lost, as well as the pressure of sap necessary to start the dormant buds into fresh growth. If a Vine is cut in June or July, when in full leaf, it will not bleed, because the vessels are then filled with air, as a result of the transpiration current. Inarching of Vines should not be attempted till they are fairly into leaf, for these reasons. If pruning is accomplished in autumn, before the wood is perfectly ripened, Vines often bleed in spring when root pressure becomes strong. This phenomenon of bleeding, when cut in spring, may be observed in various other plants, including the Birch and Maple. The former will bleed at a considerable height from the ground (12 to 15 ft.), though most strongly near the base of the trunk. Sugar is extracted from the sap of the Sugar Maple, and Rubber from the sap of various Rubber Trees. [J. F.]

§ 8. MODES OF GROWTH AND VEGETATIVE REPRODUCTION

Monopodial and Sympodial Stems.—When a seedling of a shrub or tree has completed its first year's growth, it usually terminates in a bud, covered with scales. If, on the resumption of growth next spring, this bud continues the growth of the stem or axis, the latter would be monopodial, and would continue to be so from year to year, so long as this order of growth is maintained. The Conifers are good examples of monopodial stems, particularly the species of Pinus, Abies, Picea, Sequoia, and Araucaria. If the leaders of such trees get broken, or eaten off by animals, or killed by frost, they rarely recover themselves by the production of a new, upright axis. *Araucaria excelsa* is a rare exception to this rule. If the leader is cut off for the purpose of propagation, one or more upright shoots on the old stock will result, and these may be utilized in the same way. The side branches are useless, because they do not grow into true tree shape, even though they produce roots. The side branches are secondary monopodia, continued by growth at the apex, but they always retain the same relation to the primary axis. Trees of this character may often be

improved by stopping the growth of too rampant lateral shoots, but not the leader.

Sympodial stems are very numerous, and are not the result of the continuous growth of the primary axis from year to year. For instance, a seedling Vine would be monopodial until it produces a tendril, which is the termination of the primary axis. A bunch of flowers or berries is the equivalent of the tendril, and in any of these cases the axis is continued by the growth of an axillary bud or axis that pushes the primary one to a side. It will be noticed that the tendril or bunch of flowers is always opposite to a leaf, not in its axil. A similar method of growth may be noted in the Tomato. The first bunch of flowers is really the termination of the axis of the seedling plant. An axillary bud grows strongly and pushes the bunch of flowers on one side, and in its turn terminates in a bunch of flowers, and so on indefinitely. The number of bunches on a single-stemmed Tomato is an index to the number of axes thus superposed, and forming the "sympodium" or combination of several separate axes. This mode of growth is brought about in the Willows by the dying of the terminal bud at the end of each season, and as a result of it the growth next year must be continued by an axillary bud. Sympodial branching may be observed in the Lilac and Horse-chestnuts. Whenever a stem or branch ends in a bunch of flowers, the axis afterwards dies back to the first pair of buds, which will produce two new axes, if they are leafy buds, but if flower buds, then growth must be continued from a lower pair of buds.

Fig. 43.—Racemose Inflorescence—Indefinite

Forms of Inflorescence.—When flowers occur singly at the end of an axis, as in the Tulip, it is terminal and solitary; and when only one flower is produced in the axil of an ordinary leaf it is termed axillary and solitary. More often two or any larger number of flowers are associated together on a floral axis, with or without bracts at the base of the individual flower stalks, and such an association is termed an "inflorescence". The floral axis shows greater variation in the modes of branching than the ordinary stem. The *monopodial* or *indefinite* form is seen in the Wallflower, Rocket, Lily of the Valley (fig. 43), and Laburnum, in each of which the inflorescence is a *raceme*. The lowest flower is the oldest and first to open, and is succeeded by others in *centripetal* order, and each is furnished with a stalk of its own. The *spike* is also monopodial, and differs from the raceme by the absence of stalks to the flowers, as in Orchis and Verbena. The *corymb* is a form in which the lower flower stalks are long, so as to bring the flowers all to the same level, as in Star of Bethlehem. The *umbel* has its flower stalks all of the same length, and arising from one point, as in the garden Polyanthus, Cowslip, and Cherry. The compound umbel is seen in the Carrot, Parsnip, Parsley, and Celery. The first or primary

A DUTCH HYACINTH NURSERY

(6) A BULB FARM AT WISBECH, CAMBRIDGESHIRE (Mr. J. W. Cross)

DUTCH AND ENGLISH HYACINTH FARMS

flower stalks do not bear flowers, but give rise to secondary umbels of stalked flowers. The *capitulum* (fig. 44) is seen in the Daisy, Dandelion, and Marguerite. It consists of an aggregation of small flowers or florets, in a head, surrounded by numerous bracts. The outer florets are the oldest and first to open, as in other indefinite inflorescences. The panicle is a branching inflorescence, the branches of which may be in racemes, as in the Cabbage, or in spikes, as in Beet.

Sympodial or *definite* inflorescences are fairly numerous, but all are characterized by the axis terminating in a flower which is the oldest and the first to open, but the stalk soon ceases to lengthen, and all the other flowers are produced on branches which spring from a point lower down and soon overtop the primary axis. The various forms of definite inflorescence are termed *cymes.* The *dichasial cyme* is seen in the Stitchworts (Stellaria), Lychnis, and others, in which both lateral branches are developed equally, each terminating in a flower (fig. 45). The *scorpioid cyme* is seen in Forget-me-not and Heliotrope. The *corymbose* cyme is that in which the branches all terminate on the same level, and the Sweet William comes near this type. The *panicled* cyme may be seen in the herbaceous Spiræas.

Fig. 44.—Inflorescence (Capitulum) of Dandelion

Fig. 45.—Cymose Inflorescence—Definite, the central flower opening first

Flower Buds and Pruning.—The art of pruning cannot be properly accomplished without a close study of the habit and mode of growth of each species of plant whose cultivation is undertaken. The object of pruning in each case should be strictly kept in view, and the time and method of operating guided accordingly. Apples, Pears, Plums, Nuts, and Cherries form their flower buds in the late summer and autumn previous to their expansion in spring. In most cases they are produced on short, lateral spurs, and may readily be distinguished soon after the fall of the leaf by their plump and rounded form. Those of the Morello Cherry, Peach, Nectarine, and Black Currant are scattered along the shoots of the previous year, and these must be retained full length or only the weak tips removed. Red and White Currants flower chiefly on buds thickly clustered on the old wood, so that the young shoots should be cut away almost to the base, except the leaders of young bushes, which may be left 4 to 6 in. long. The Vine flowers on the wood of the current year, so that the

laterals may be pruned back to one or two good buds near the main rod. Hybrid Perpetual and bush Tea Roses produce their flowers on the growths of the current year, and for this reason may be pruned hard back to get good flowers. Climbing Tea Roses, like Gloire de Dijon and Bouquet d'Or, Climbing Hybrid Teas, Noisettes like William A. Richardson, and Wichuraiana Roses, must not have their long young stems cut hard back, or few or no flowers will be obtainable during the forthcoming season. Banksian Roses produce their flowers on shoots of the first or second year's growth from the main stem, and these secondary or tertiary shoots must be tied or nailed up full length. All these climbing types require thinning chiefly, and two-year-old stems removed to prevent crowding. Deutzias, Guelder Roses, Lilacs, Cytisus, Genista, Forsythia, *Hydrangea hortensis*, and other shrubs that set their buds on wood of the previous year must not have these cut back till after the flowering period, and then it should be done at once where necessary.

Propagation by Roots.—Many plants may be propagated by cutting up the roots into short lengths and inserting them as cuttings, and in the absence of seeds they may be rapidly increased in this way. The roots of the Gean (*Prunus Avium*), Plum stocks for varieties of garden Plums, Poplars, and English Elm naturally develop suckers on their roots and may be propagated in this way. The roots of Bouvardias, *Senecio pulcher*, *Anemone japonica*, *Ailanthus glandulosa*, Seakale, Horse Radish, and many others may be cut into short pieces and inserted as cuttings, when they give rise to buds which grow into plants. Some of these roots are fleshy, but in any case they can only give rise to buds owing to the presence of formative matter or reserve food in them, usually starch. The underground parts of Mints, Solomon's Seal, Lily of the Valley, and many others used for propagation are not roots but rhizomes or underground stems, and branches in the case of the Potato and Jerusalem Artichoke.

Propagation by Stems.—This is the most common method of increasing plants, whether by cuttings, budding, grafting, inarching, layering, rhizomes, corms, eyes, or runners. Due care must be taken as to the likely places where starch or other reserve material may be stored. For instance, a Dahlia cutting, with a piece of the old tuber, will strike with more certainty than a piece of the young stem alone. The same applies to cuttings of Everlasting Peas, *Lychnis chalcedonica flore pleno*, *L. dioica flore pleno*, *Gypsophila paniculata flore pleno*, Begonia Gloire de Lorraine, and other choice varieties, which it is desirable to keep true to name. They should be cut as near the rootstock as possible. The same reason holds good with cuttings of Roses and many other shrubs, to be cut at a joint, or with a heel of the old wood. Such cuttings are always more solid at a joint than elsewhere, and less liable to damp off, but there is always a greater storage of food in those places than between the joints, because it comes from the leaf, and the bud or young shoot in its axil has to be fed.

Propagation by Leaves.—Many Ferns, including a large number of

Aspleniums (fig. 46), *Bryophyllum calycinum* (fig. 46), *Tolmiæa Menziesii, Cardamine pratensis,* and its double variety naturally produce buds on the margins, base, or upper surface of their leaves, which grow into plants under conditions favourable to the production of roots. The leaves of Begonia Rex and its varieties may be induced to form buds artificially by cutting through the thick ribs, laying the leaves on sand, pegging or fastening them in position in a moist, warm frame, till small tubers bearing a bud are formed. On the other hand, those leaves may be cut into strips, each with a thick rib, and inserted as cuttings in sand. Leaves of Gloxinias, Streptocarpus, and allied plants may be dealt with in the same way. The fleshy leaves of Cotyledon (Echeveria), *Sempervivum tabulæforme,* and the bulb scales of many Lilies and Hyacinths may be pulled off in their entirety and laid on sand, kept moist, or lightly dibbled into the sand, and they will form small or young plants. Lastreas, Scolopendriums, and other ferns often form a small plant at the base of the leaf stalk, or may be induced to do so by inserting the thick base in sand and keeping it moist. Reserve materials are present in all these cases, together with a plentiful supply of water within the tissues, and this serves to keep the leaves alive and carry the food materials to the point where a tuberous callus is formed, from which the roots are emitted. The leaves of the Cotyledons have a cuticle as well as a layer of wax, which prevents the escape of their sap, and they must not be kept wet by too frequent watering, or they will damp off. It is possible that most leaves could be rooted in this way if they could be kept alive without damping till roots are formed.

Fig. 46.—Formation of Buds on Fronds and Foliage Leaves

1, 2, on the pinnules of *Asplenium bulbiferum*; 3, on the margins of the lobes of the leaves of *Bryophyllum calycinum*.

All the above are methods of *vegetative* or *asexual* reproduction, and their object is to multiply the plant and keep varieties true to character and name. They furnish a means of increase where no seeds or spores

are obtainable, or might not come true to the parent, and in the case of choice and rare ferns may be the only means of perpetuating them. None of the above processes gives rise to a new individual, but merely young or rehabilitated pieces of the old ones, and this is what *vegetative* reproduction implies. [J. F.]

§ 9. THE FLOWER AND ITS FUNCTIONS

The Parts of a Flower.—Phanerogams, or flowering plants, differ from Ferns and other vascular plants in the great modifications which the leaves have undergone in the construction of the flower. A complete flower consists of four sets of organs, termed respectively the calyx, corolla, stamens, and pistil. Each member of these sets or whorls of organs consists of a leaf, modified according to the function which it has to perform in the economy of the plant. The axis bearing these floral leaves ceases to lengthen when the flowering stage of the plant has been reached.

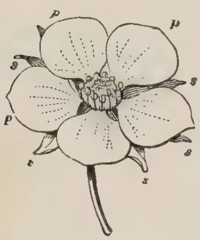


Fig. 47.—Strawberry Flower

p, petals; *s*, sepals.

Fig. 48.—Campanula Flower, showing a regular flower with five-parted calyx and corolla. The leaf on the pedicel is called a bract.

1. *The Calyx.*—The number of parts forming the calyx varies, but four (as in the Wallflower) and five (as in the Buttercup) are extremely common numbers. These parts are situated on the outside of the flower proper, and when free from one another are termed *sepals*; but when more or less united they are described as the segments, lobes, or teeth of the calyx, according to the length of the free portion. Usually they are small, green, and serve to protect the other parts of the flower. In the Christmas Rose (*Helleborus niger*), Marsh Marigold (Caltha), Delphinium, and Aconitum they are large, highly coloured, showy, and perform the function of the corolla in attracting insects.

2. *The Corolla.*—The second set of organs, proceeding inwards, constitutes the corolla; and, if the parts are free, they are termed *petals*, as in the Buttercup, Rose, Camellia, Sweet Pea, and Strawberry (fig. 47). Very often all the pieces are united for a greater or less part of their length, when the corolla is said to be *gamopetalous*, as in the Primrose, Salvia, Dandelion, Stephanotis, Gardenia, and Campanula (fig. 48). The lower part of these flowers is the *tube* and the expanded portion the limb; the latter is often two-lipped, as in Salvia and Lamium (fig. 49, I). The corolla is bell-shaped in Campanula, funnel-shaped in Convolvulus, and so on. It is usually the most showy part of the flower, protecting the inner parts, but designed more particularly to attract and guide insects to the nectar. In the Christmas Rose, Winter Aconite, and Globe Flower

(Trollius), the petals are small and modified to form nectaries, and this would explain why the sepals are large and highly coloured. The modifications are endless, and usually have some reference to the method of fertilization. The corolla is said to be *regular* when all the parts are alike, but *irregular* when they are of different sizes, shapes, or disposition, as in Salvia, Snapdragon (fig. 49, J), or Sweet Pea.

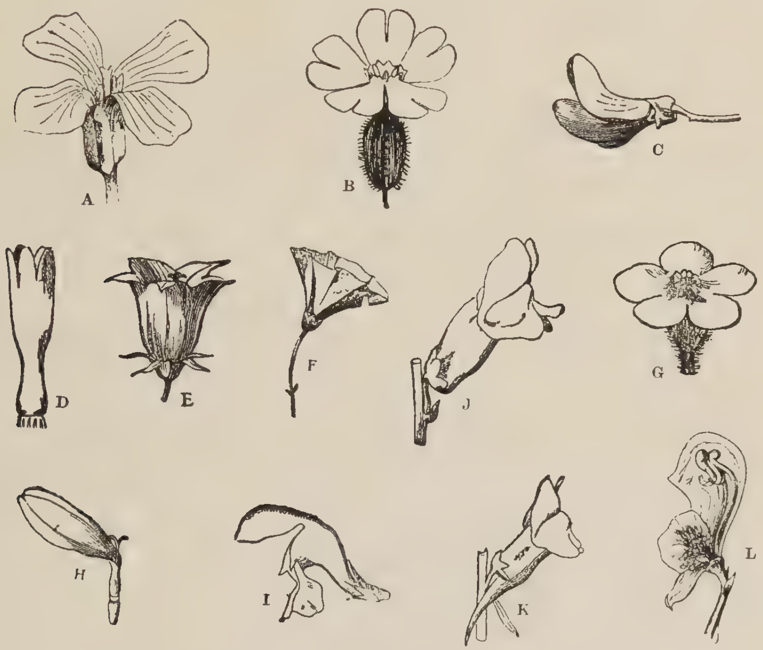


Fig. 49.—Forms of Corolla

A, Cruciate. B, Caryophyllaceous. C, Papilionaceous. D, Tubular. E, Campanulate. F, Funnel-shaped. G, Rotate. H, Ligulate. I, Labiate. J, Personate. K, Personate and spurred. L, Nectaries.

In many flowers the outer and inner whorls, representing calyx and corolla, may be of the same texture and colour, and in such cases they are collectively termed the *perianth*, as in Daffodils, Lilies, Amaryllis, Tulips, Crocuses, Irises, and other Monocotyledons. In many Dicotyledons, however, there is only one set of organs, which may be green or coloured, and the term *perianth* is also applied to them, as in Daphne, Marvel of Peru, Knotweeds (Polygonum), and Docks. The large white leaf of the Arum Lily is not a corolla, but a large bract enclosing a spike of small flowers, and termed a *spathe*.

3. *The Stamens.*—These are situated just inside the corolla, and may vary from one to a hundred or more in one flower. They consist of a *filament* or stalk, comparable to a leaf stalk, and an *anther* on the top, corresponding to the blade of the leaf. The filament may be absent but the anther is essential, as it contains the powdery-looking pollen grains (fig. 50) that fertilize the embryo cell. The filaments may be free from

one another, or united in one, two, or more bundles, these various conditions being indicated by special names in the textbooks, which may be consulted where necessary. They may also be seated on various parts of the flower, and the distinctions are very valuable in systematic botany.

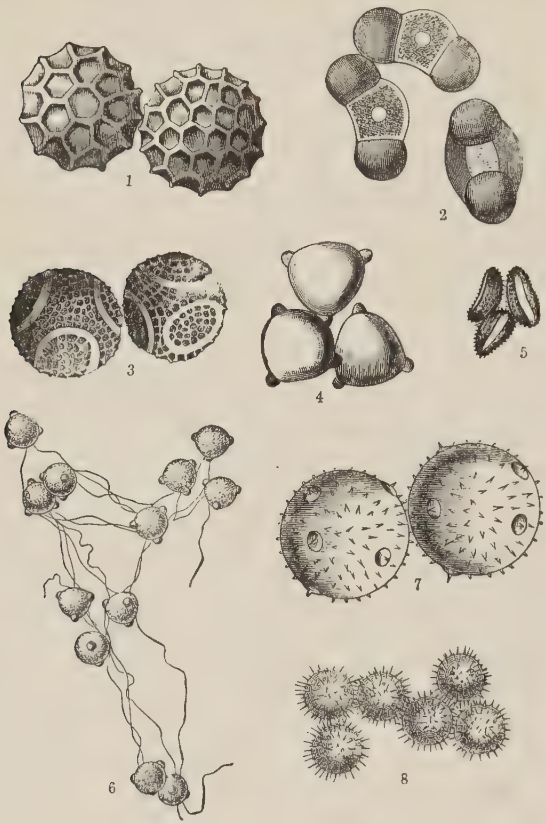


Fig. 50.—Pollen Grains highly magnified

1, *Cobæa scandens.* 2, *Pinus Pumilio.* 3, *Passiflora kermesina.* 4, *Circœa alpina.* 5, *Nymphœa alba.* 6, *Epilobium angustifolium.* 7, *Cucurbita Pepo.* 8, *Hibiscus ternatus.*

4. *The Pistil.*—This includes all the organs in the centre of the flower, and being the female parts of the same, are as essential to it as the stamens. Taking the White Lily as an example, the lower, inflated portion is named the ovary, the long stalk on the top of it the style, and the knob on the apex of that the stigma. If the ovary be cut across, it will be seen to have three cells filled with numerous ovules or young unfertilized seeds. The three cells are an indication that the pistil consists of three *carpels* or modified leaves closely united. The pistil of the Buttercup, Potentilla, and Strawberry (fig. 51) consists of numerous carpels, all free from one another, and popularly termed seeds, but each consists of an ovary, style, and stigma. The Barberry, Pea, and Peach have a pistil consisting of one carpel in each flower. The number of carpels that go to the composition of the pistil of the Poppy may be determined by the number of rays to the stigma and the incomplete partitions that project into the interior of the ovary. This may be done in the Mallow, Carnation, and Carrot by counting the number of styles, and in Geranium, Pelargonium, Mint, and Salvia by counting the number of stigmas.

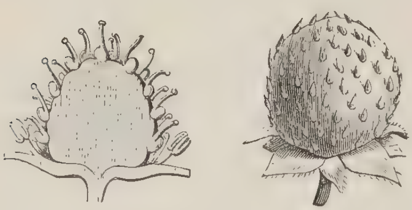


Fig. 51.—Strawberry—with Section, showing thickened receptacle bearing the true fruits or pips on the surface

5. *The Ovule.*—A young seed before it has been fertilized is termed an ovule. A Buttercup or Strawberry contains only one ovule in each carpel; a Cherry or Peach contains two, but only one reaches maturity. The Pea may have from four or five to a dozen, arranged along the edges of the ventral suture, one of the two separable edges of the pod. The Pansy

Fig. 52.—A Monœcious Plant

1, Pistillate flowers on upper part of twig of Oak (*Quercus pedunculata*); staminate flowers in drooping catkins below (nat. size). 2, Single pistillate (female) flower. 3, Three staminate (male) flowers. × 4.

has numerous ovules, in three distinct rows on the side walls of the ovary, and defined as *parietal*. In the White Lily they are on the inner angles of the cells of the ovary, and therefore *axile*. The part to which they are attached is termed the *placenta* in each case. The placenta is free and central in the Chinese Primula, and the ovules are inserted all over it.

6. *The Receptacle.*—After all the parts of a flower have been removed there remains, as a rule, a small core or axis, which is the *receptacle*, and

is really a very short piece of stem that bore the various floral leaves just described. It undergoes many modifications in different plants. In the Buttercup and Wallflower it remains small; in the Strawberry it becomes enlarged and pulpy (fig. 51); in the Raspberry and Bramble it becomes large, conical, and spongy; in the Apple it grows up around the carpels, completely enclosing them, and, though only a fleshy, cellular flower stalk, it forms the edible portion of the fruit. The receptacle of

Fig. 53.—A Diœcious Plant

1, Twig of Crack Willow (*Salix fragilis*), with pistillate (female) catkins. 2, Twig of same with staminate (male) catkins (nat. size).

the Cherry or Peach forms a little cup round the base of the ovary, and carries the sepals, petals, and stamens on its edges. In the Rose or Brier it forms a hollow tube enclosing the carpels, and becomes the brightly coloured hip at maturity. The Fig is also a hollow receptacle, enclosing a whole inflorescence of numerous small flowers.

A flower is said to be *hermaphrodite* when it contains both stamens and pistil; *male*, when it contains stamens only; *female*, when only the pistil is present. A plant or tree is *monœcious* when male and female flowers occur on different parts of the same individual, as in Begonia, Cucumber, Marrow, Oak (fig. 52), and Melon; and *diœcious* when only

male flowers occur on one individual, and only female on another, as in the Willow (fig. 53), Poplar, Aucuba, and Ash.

Pollination and Fertilization. — When pollen is carried from the stamens of one flower by insects, the wind, or other agency, and deposited on a stigma of another flower, the process is called *pollination*. If the pollen is placed on the stigma of the same flower, that would be self-pollination; and if the flower accomplishes this itself, as it frequently does, that would be automatic self-pollination. The word *fertilization* is often loosely used to imply the same act, but no fertilization can really take place till the pollen tube has reached the germinal vesicle in the ovule and formed a union with it.

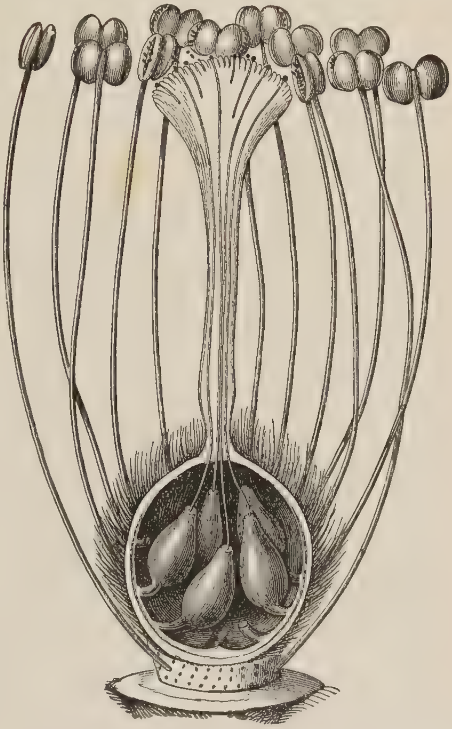


Fig. 54.—Flower of Cistus: Sepals and Petals removed. The Stamens are hypogynous, and some of them have their Anthers in contact with the Stigma. The Pollen Tubes are shown passing down the Style and entering the Ovules.

Sexual Reproduction. — Except in minor details this is accomplished much in the same way in all vascular plants, which include Ferns, Selaginellas, and their allies. The pollen grains of a flowering plant are equivalent to the microspores of a Selaginella; and the anther in which they are produced to the microsporangium of Selaginella. The germinal vesicle or *egg cell* is equivalent to the *megaspore*, and the embryo sac in which it is produced to the *megasporangium* of a Selaginella. The pollen is the male element and the egg cell the female. A pollen grain has two coats or skins, and when it reaches the stigma the inner coat soon after protrudes and grows down the loose, conducting tissue in the interior of the stigma and style, in the form of a blind or closed tube (fig. 54), then passes into the ovary, and enters the *micropyle* or opening of the ovule until it comes in contact with the egg cell (fig. 56). The growing or elongating pollen tube contains two nuclei, and the first and larger one fuses with the nucleus of the egg cell and *fertilization* is complete. In other words, the male and female elements have united to form one cell, which forthwith develops into an *embryo* or new individual. If the pollen has been brought from another plant of the same kind, the embryo will inherit the characters of both parents, and, though it may not seem to differ much from either when it grows into a plant, it is usually more vigorous than an embryo which is the

Fig. 55.—Section of Style of *Lilium Martagon*, showing Pollen Grains on the Stigma, and sending down their Tubes along the conducting tissue of the Style

result of self-fertilization. This is sexual reproduction, and is vastly different from the increase of numbers secured by cuttings, layers, and offsets, which are merely pieces of the individual from which they were taken.

Cross-breeding and Hybridization.—When pollen is taken from the flower of one variety and placed on the stigma of another variety of the same species, and plants raised from the seeds so obtained, the process is rightly termed *cross-breeding*. Of the hundreds of varieties now in existence of the Sweet Pea, Carnation, and Chinese Primula, none of them are hybrids, although cultivators often speak loosely of hybridizing them. A *hybrid* can only be produced by taking pollen from the flower of one species and placing it on the stigma of another species, such as *Cattleya labiata* and *C. bicolor*, *Pelargonium zonale* and *P. inquinans*, *Begonia boliviensis* and *B. Pearcei.* Species belonging to different genera are sometimes hybridized, such as *Cattleya labiata* and *Lælia crispa*, and the

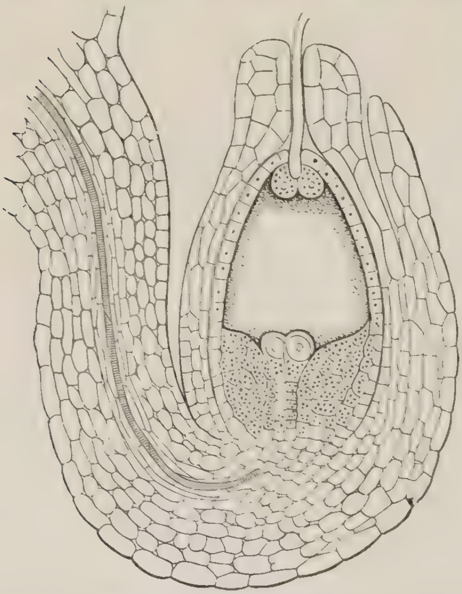


Fig. 56.—Section of an Ovule, showing the entry of the Pollen Tube into the Embryo Sac

Fig. 57.—Lythrum. Section of Flower, showing two rows of Stamens—one short, one long. The Style is short.

resulting seedlings named, Læliocattleya or Catlælia, by compounding the names. Three genera have been united by crossing the product of the first two with a third, namely, Brassavola, Cattleya, and Lælia, and indicated by the name Brassocatlælia.

Hybrids are by no means always sterile, as was at one time supposed, when they were termed "mules". The hybrid progeny of Orchids, Begonias, Roses, and other plants may be used as parents for still further improving the race. To what extent hybridization can be carried is uncertain, as it largely depends on sexual affinity. Some varieties refuse to cross, and many species refuse to hybridize with one another. The difficulties are increased when it is attempted to mate species belonging to different genera, and the members of different natural orders refuse to hybridize at all. When species are distantly related, the possibilities of hybridizing them can only be determined by experiment. When this is done artificially it largely depends on the skill of the operator, who must get the pollen in mature and good condition, and apply it to the stigma when perfectly developed and receptive, either moist, as in an Orchid or Rose, or covered with a fine downy pile, as in a Carnation, Begonia, Chrysanthemum, or Cineraria. To make sure of the pollen applied being effective, the anthers of the flower to be operated upon must be removed before they have burst, and after applying the pollen the flower should be covered with thin gauze to exclude insects for a few days till the pollen has time to take effect. In winter and under glass this is scarcely necessary, and in summer tiffany may be put over the open ventilators to exclude insects.

Plants grown for seed in the open field must be kept widely apart, if they are at all closely related, or insects may mix the stocks by carrying the pollen of one to another. Varieties of the cabbage tribe, such as Cauliflower, Kale, Brussels Sprouts, and Cabbages are very liable to be indiscriminately crossed in this way and rendered useless. Sports may be explained by the characters of a cross-bred or hybrid plant becoming separated or dissociated in certain of the buds on the stem, and the flowers of such buds, or the shoots from them, are of a different colour.

Various Forms of Fruit.—As the result of the fertilization of the egg cell and the production of an embryo, the pistil becomes the young fruit. Usually this includes only the ovary and stigma, with the style if present, as well as the ovules. In those cases where the *receptacle* grows up around and adheres to the ovary walls, that also forms part of the fruit, as in the Cucumber, Melon, Apple, and Daffodil, with the withered remains of the flower on the top of it. The simplest forms of fruit may be seen in the Buttercup and Strawberry, in which the small, mature fruits resemble seeds. In the Christmas Rose and Columbine it becomes dry, splits along one edge, and is termed a *follicle*; in the Pea it splits along both edges and is named a *legume* or *pod*. The Pansy, Poppy, and Snapdragon have dry seed vessels, opening by valves or pores and named *capsules*. The fruit of the Gooseberry and Currant is a true *berry*, because inferior, one-celled, and pulpy. The fruit of the Apple is called a *pome*.

The inner wall of the ovary becomes bony in the Cherry, Peach, and Plum, while the portion between this and the skin becomes pulpy; the fruit is a *drupe* (fig. 58). That of the Raspberry and Bramble consists of an aggregation of drupels or small drupes. The Mulberry fruit resembles it, but is made up of a large number of flowers, the perianth of which becomes fleshy, and the fruit is termed a *sorosis.* This sisterhood of clustered fruits is carried still further in the Pineapple, the flowers, pistils, bracts, and axis forming one pulpy mass. The Fig has a fruit consisting of a whole inflorescence, enclosed in the hollow, pulpy axis, each seed, so-called, being a tiny fruit from the botanist's point of view.

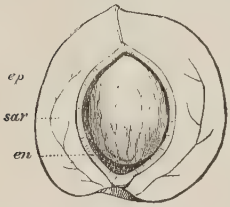


Fig. 58.—Section through the Fruit (Drupe) of a Plum, showing the Epicarp (*ep*) or Skin, the Sarcocarp (*sar*) or Flesh, the Endocarp (*en*) or Stone. In the centre is the solitary Seed or Kernel.

The circumstances which favour the ripening of fruits under glass are a drier atmosphere, plenty of air, and a higher temperature than usual to secure the chemical changes, whereby harsh and acid juices may become pleasant to the palate, and starch and other reserve matters may be converted into sugar. Black grapes require to be shaded by their foliage, and white varieties to be exposed. Cucumbers require a thin shading to prevent the development of too much carbon in them, which means the loss of the green colour. Apples, Pears, Plums, Cherries, Peaches, and Nectarines require full exposure to sunlight to change the chlorophyll granules in the skins into red and yellow ones. Apples and Pears grown in pots take on the brightest and darkest colours if stood out-of-doors to mature.

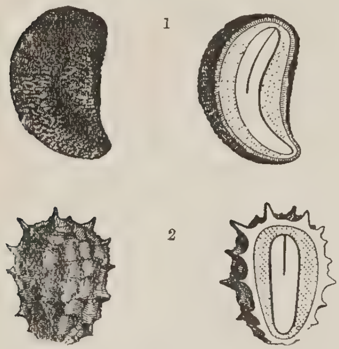


Fig. 59.—Seeds, showing the Outer Skin or Testa with rugged prominences or projections. The sections show the Seeds cut lengthwise, and show the Embryo with its two Cotyledons, and the Radicle surrounded by the Perisperm.

1, Rue (*Ruta graveolens*). 2, Snapdragon below.

Seeds.—When the ovule is fertilized by the union of the nucleus of the pollen tube with the egg cell it becomes a seed. At this stage it consists of three parts: (1) The *testa,* or skin, made of two layers or coats, and belonging to the mother plant; (2) the *endosperm,* a mass of tissue developed to nourish the embryo; and (3) the *embryo* or young plant. The endosperm and embryo are new developments, resulting from the act of fertilization. As the seed progresses to maturity it undergoes great changes, and, in many cases, remarkable developments (figs 59, 60). The testa may remain thin and membranous, especially in those cases where it is covered by the walls of the fruit at maturity and after it has fallen away from the mother plant, as in the Buttercup, Clematis, and Chrysanthemum, the fruits of which must not be mistaken for seeds. The testa also remains thin in the Peach and Cherry, where it is protected by the bony endocarp or stone. It becomes leathery, spongy, or fleshy in different species of Iris,

and crustaceous in the Honeysuckle; while it may be much wrinkled, crustaceous, tubercled, or warted in species of Delphinium. Tubercled seeds may be found in Lychnis, Silene, and Stellaria; netted or pitted ones in Poppy, Passionflower, and their allies. In the Willow Herb (Epilobium) the seeds develop a long pencil of hairs at the top, and in the Willow and Poplar the parachute of hairs arises at the base; and in all cases the hairs are intended to assist the dissemination of the seeds by the wind. This, also, is the intention where the testa develops round the edges or at both ends into a membranous expansion or wing, as in the Bignonia and Moonseed families, in the Stock, Arabis, and many others.

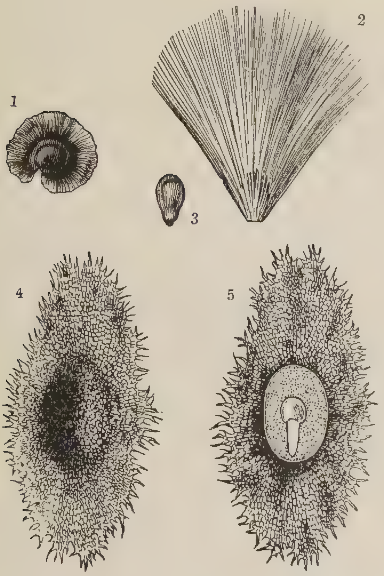


Fig. 60.—Seeds with the Testa or Skin winged, or provided with a tuft of Hairs, the object in each case being to secure the dispersal of the Seed

1, Lepigonum. 2, 3, Aspen. 4, 5, Cinchona.

As the seed matures, the endosperm grows and becomes fleshy, horny, or mealy in different families, and fills up the interior of the seed to a greater or less extent, or may disappear altogether, as in the Crucifers and Rose families, where the embryo uses it all up before maturity. The embryo may remain small or grow to fill the seed, and intermediate stages are very numerous. It may store all the food materials in itself and the cotyledons may remain thin or become fleshy. At maturity the seed assumes various colours, such as red, brown, white, or black, and these colours are a sign that growth has ceased. The testa dries up, but the endosperm and embryo remain alive and retain their protoplasm and other contents, though the embryo alone is capable of resuming growth in most cases. The Castor-oil seed is an exception, for the endosperm also grows during germination.

Germination.—The essentials to germination are air, moisture, and a suitable temperature. The oxygen of the air is necessary for the purpose of respiration, to keep the embryo alive even while it is resting in the dry seed; but before germination can take place it must respire more freely to induce the chemical changes necessary for the resumption of growth. Moisture is required to soften the testa and other hard parts with which it may be surrounded, as well as to swell up the tissues of the embryo and endosperm, where such is present. A certain degree of heat is necessary before any growth can take place, and this has to be determined in each particular case. The seed of the Sycamore may germinate at freezing-point, but many other plants require a considerably higher temperature. On the other hand, very few species of plants will germinate in a higher temperature than

104° to 108° F. The best temperature, therefore, for germinating seed lies somewhere between freezing-point and the last-named figures. The temperature at which seeds will germinate most quickly is the best in all cases; hence the value of ascertaining this approximately. As soon as germination is completed most plants will thrive best with less heat, more air and light, but particularly those seedlings whose cotyledons rise above-ground and become green.

Seeds which contain no endosperm usually germinate very quickly because the embryo already contains all the reserve food within itself, as in the Cabbage, Turnip, Mustard, and Willow. The Almond, Plum, and Cherry take a long time to soften the hard shell in which the seed is enclosed, while endosperm is absent. The seeds of many trees fail to germinate at all if kept dry over the winter before being sown. If allowed to get dry, the seeds of Canna often require filing and steeping in warm water before they will absorb sufficient water to induce germination. Carrots, Parsnips, Parsley, and Onions take a long time to germinate, because the small embryo has to feed on the endosperm and grow to some size before it can leave the seed. Grass seeds have a starchy endosperm, but germinate quickly because the embryo is situated on the outside of the mass and remains attached to it by the cotyledon while the first leaf rises above-ground. The stored materials are converted from insoluble into soluble matters, which the embryo can absorb. Starch is changed into liquid sugar or glucose by a kind of ferment set up in the endosperm or in the tissues of the embryo itself. Many seeds contain a large quantity of oil, which gets changed into starch and finally into sugar, before being used up by the embryo. Light is unnecessary for these processes, and is detrimental chiefly by drying up the moisture and causing great fluctuations of temperature. After the seed leaves are expanded light is of the greatest importance. Oily seeds soon lose the power of germination; starchy seeds, like wheat and barley, and the seeds of the Pea family, which contain no endosperm and little or no oil, may live for ten to forty years, but the process of breathing alone would, in the course of a relatively short period, consume the live substance of any seed. [J. F.]

SECTION III

Methods of Propagation

In commercial gardening enormous numbers of plants are disposed of each year from the open ground and from under glass, and as soon as one crop is finished, another, as a rule, is ready to take its place. To maintain the equilibrium it is obvious that in accordance with the disposal of the plants a corresponding number must be raised each year.

Crops are raised in various ways, viz.: From (1) seeds; (2) cuttings of stems, leaves, or roots; (3) layers; (4) runners; (5) suckers; (6) offsets; (7) bulbils; (8) division of the rootstocks; (9) budding; (10) grafting and inarching. The commercial grower naturally adopts the method of propagation that will produce him a saleable crop within the shortest possible period, although a particular crop may be raised by more than one method.

Seeds.—Although in a state of nature this is the natural means of reproducing plants, it is not always the best or most satisfactory under other conditions. A whole host of plants, however, are raised from seeds each year, and in this way the seed trade already referred to at p. 2 is kept well employed. Such plants as annuals and biennials are necessarily raised from seeds, because they cannot well be perpetuated in any other way, owing to the short time they live. All natural species that ripen seed in our climate, and many florists' flowers, may be raised from seed, and the young plants will reproduce all the features of their parents. In the case of many florists' flowers, however, like Begonias, Dahlias, Chrysanthemums, Carnations, Snapdragons, Pentstemons, Petunias, Gloxinias, and many others, special varieties are propagated by other means, as they are unlikely to come perfectly true if raised from seed. Variations may and do occur as the result of cross-fertilization by insect agency, and this is often sufficient to alter the character of the flowers. All choice varieties of fruit trees and roses are not raised from seeds, except in the first instance. Most vegetable crops, being of an annual or biennial nature, are raised from seeds. Great care, however, is taken by raisers to keep their stocks of special varieties quite pure and free from cross-fertilization with inferior strains. The plants to bear seeds are grown in places as far as

possible from those of a similar nature, to prevent the pollen being carried from one to the other.

Seeds vary considerably in size, from almost dust-like grains to that of Peas, Beans, Acorns, and upwards, to Coconuts. They are borne either singly or severally in their pods or ovaries, some plants like Begonias, Poppies, Marrows, &c., having from 300 to 600 seeds or more in a pod, while there are several thousands in many orchids. Whatever the size may be, each seed is the result of an ovule having been fertilized by the contents of the pollen tube that penetrated the tissues of the pistil from the stigma downwards, as the result of the pollen grains germinating. In the case of Fern spores—which are popularly known as "seeds"—the process is quite different, and is explained in the article on Ferns in Vol. II.

Each seed, when thoroughly ripe, contains sufficient nourishment to start the young plantlet in life under favourable conditions, and the main object of the cultivator is to get the seed-leaves up to the light as soon as possible, so that they may be able to assimilate the carbonic acid gas from the atmosphere to develop further tissue. Some seeds germinate more quickly than others, and seeds of the same plant will germinate either quickly or slowly according as it is in a favourable temperature or not. Under the best conditions some seeds take a long time to germinate, often owing to the extreme hardness and thickness of their coats. Experience has proved, however, that hard-coated seeds will germinate readily as soon as they drop from the parent plant; but if kept for a few months, and then sown, a considerable time may elapse before they begin to sprout. For this reason seeds of Cannas, Nelumbiums, and many of the Leguminosæ are often filed before being sown, to reduce the thickness of the hard bony coat surrounding the embryo plant within. It may be worth while to quote the following remarks of the late Herr Max Leichtlin, from the *Gardener's Assistant*: "If practicable, it would be best to sow all seeds of hardy plants at once when ripe; we only delay sowing for the sake of convenience, because we should, in the case of autumnal sowings, be obliged to house a very large number of pans and boxes of young plants too small to pass the winter outside. Hard-shelled seeds must be sown at once, also all seeds of hardy bulbous plants. If seeds of Colchicum be exposed to the air for a few days, not more than 5 per cent come up within a year, and the rest may take five years to germinate, whereas, sown as soon as the seed pod splits, 30 per cent will germinate in the first year. Delay sowing the seeds of Lilium, Fritillaria, Tulipa, &c., and you will lose from 20 to 80 per cent. Campanulas and Ostrowskya readily germinate when sown at once, but if sowing is deferred till spring the seeds will probably lie dormant for a year, if they do not perish altogether."

The following data as to the number of days taken by various seeds to germinate may be of interest. The night temperature was about 60° F., and the day temperature ranged from 65° to 70° F. Those marked with an asterisk (*) were sown in the open air.

SHOWING ELECTRIC SEED-CLEANING MACHINERY (James Carter & Co.)

(7)

SHOWING MACHINERY FOR FILLING SACKS WITH SEED

SEED WAREHOUSES

Name of Plant.	Date of Sowing.	Date of Germinating.	Number of Days.
African Marigold	April 4	April 9	5
African Marigold*	,, 8	,, 29	21
Antirrhinum, Sunlight	March 3	March 13	10
,, The Bride	,, 7	,, 13	6
Aquilegia cœrulea	,, 3	,, 24	21
,, glandulosa	,, 3	,, 28	25
,, hybrids	,, 3	,, 23	20
Auricula, Alpine	,, 3	,, 18	15
Calampelis scabra	April 8	April 19	11
Calendula, Meteor	,, 4	,, 10	6
Callistephus hortensis*	,, 8	,, 22	14
Candytuft	,, 11	,, 15	4
Centranthus macrosiphon*	,, 8	,, 22	14
Chrysanthemum, tricolor	,, 4	,, 14	10
Chrysanthemum, tricolor*	,, 8	,, 22	14
Clarkia pulchella*	,, 8	,, 22	14
Dahlia, double	,, 10	,, 15	5
French Marigold	,, 4	,, 11	7
Gaillardia aristata	,, 5	,, 12	7
,, grandiflora	,, 5	,, 12	7
Galega officinalis	,, 8	,, 12	4
Gilia tricolor*	,, 8	,, 22	14
Godetia	,, 4	,, 8	4
Godetia*	,, 8	,, 22	14
Hibiscus africanus	,, 8	,, 22	14
Hollyhock, double	,, 4	,, 11	7
,, single	March 3	March 11	8
Ipomœa purpurea	April 4	April 14	10
Lavatera arborea, var.	,, 10	,, 15	5
Nicotiana affinis	March 3	March 13	10
,, sylvestris	,, 3	,, 24	21
Papaver nudicaule	April 4	April 12	8
,, ,, double	,, 11	,, 15	4
Pea, Everlasting	,, 8	,, 19	11
Petunia grandiflora	March 3	March 12	9
Pyrethrum aureum	,, 1	,, 7	6
Solanum giganteum	,, 6	,, 25	19
,, pryracanthum	,, 3	,, 25	22
,, robustum	,, 3	,, 25	22
,, Warscewiczii	,, 3	,, 25	22
Stocks, Ten Week	April 4	April 10	6
Sweet Sultan	,, 10	,, 15	5
Whitlavia grandiflora	,, 4	,, 9	5
Zinnia elegans	,, 5	,, 9	4
,, Haageana	,, 4	,, 10	6

The table on next page shows the number of days it took various vegetable crops to germinate from seeds sown in the open air.

Vitality of Seeds.—While some seeds retain their vitality or power of germinating for twenty years or more, it is generally safer to utilize fresh and well-ripened seed to secure good plants. The stories circulated as to the seeds of "mummy" wheat germinating after two thousand or three thousand years have been discredited long ago, and need not be considered. As a rule, fleshy seeds like Peas, Beans, Acorns, Horse-chestnuts, Sweet Chestnuts, and Walnuts lose their germinating powers more readily than smaller and less fleshy seeds; but the latter also deteriorate if kept more than two or three years. In the case of Cucumbers and Melons, growers generally consider that they obtain a

Name of Crop.	Date of Sowing.	Date of Germinating.	Number of Days.
Beet, Blood Red	March 21	April 21	31
,, Dell's Black	,, 27	,, 23	27
Broad Bean, Early Long Pod	April 1	,, 29	28
Carrot, Early Scarlet Nantes	,, 4	,, 21	17
,, Long Surrey Red	March 14	,, 17	34
French Bean, Canadian Wonder	July 14	July 25	11
Lettuce, All the Year Round	March 19	April 4	16
,, Commodore Nutt	Feb. 2	March 12	39
,, Paris White	March 19	April 4	16
Onion, White Spanish	April 1	,, 29	28
Parsnip, The Student	March 21	,, 30	40
,, ,, ...	,, 27	,, 22	26
Pea, Veitch's Perfection	July 14	July 23	9
Spinach, Victoria	April 1	April 17	16
Turnip, Early Snowball	March 14	April 1	18
,, ,, ,, ...	,, 27	,, 13	17

greater percentage of plants from two-year-old seed than from one-year-old, which would rather indicate that they require a further period to mature properly after being taken from the fruit and cleansed.

Seed Sowing.—Seeds are sown in the open air either "broadcast" or in "drills", and under glass in pots, pans, or boxes of varying sizes. In the latter case the gardener mixes his compost beforehand, and drains his seed pans or pots more or less carefully and elaborately according to the class of seeds he intends to sow. Special pains are taken with minute seeds such as those of Begonias, Gloxinias, Rhododendrons, &c., and with the spores of Ferns. The gritty surface soil is rendered very fine by passing through sieves of small mesh, and when pressed down firmly makes a fairly solid rooting medium for the plantlets, and also prevents the seeds from dropping down too far from the light. In the case of Orchids, which are now raised from seeds in thousands, the dust-like seeds are sown on the surface of the mossy or fibrous compost in which the parent plant is growing, the little plants being transferred to thimble-like pots when large enough for the purpose.

In the open air, market gardeners and farmers prepare their soil also in accordance with the nature of the seeds. For small seeds the ground, after being ploughed or dug, is well harrowed or raked, and rolled if necessary to secure sufficient firmness. When large quantities of seed are being sown it is more economical and quicker to use a drilling machine. The seeds are put in a box, and drop through a slot at regular intervals in the drills that are made as the machine is drawn or pulled over the surface. The depth of the drills and the distance apart are regulated beforehand. Generally speaking, however, seeds are sown far too thickly, and in the case of such crops as Carrots, Parsnips, Turnips, Beet, Mangels, Peas, and Beans about 95 per cent of the seedlings have to be destroyed to make room for the others to grow. The waste is not so great with crops that are to be transplanted, as every plant almost may be utilized.

When large areas are to be sown broadcast a sowing fiddle (fig. 61)

is sometimes used. This contrivance takes its name from the fiddling action of the operator when distributing the seeds. It consists of a light canvas-covered box frame, which is suspended by a strap from the right shoulder, and is carried under the left arm. At the base of the box is a neck with a controlling slide through which the seed passes, its flow being made continuous by a jigger action from an eccentric from a spindle which carries at its bottom a distributing disk. This disk, which has four radiating ribs, is actuated by means of a thong which forms the string of the bow, and which is passed once round the spindle. When reciprocated, as in fiddling, the bow causes the disk to revolve rapidly in alternate directions, thus giving the seeds a throw of 15 to 30 ft. Where Radishes are grown extensively under glass the sowing fiddle is often used for sowing the seeds. Generally speaking, however, it is more of a farmer's than a gardener's implement.

Fig. 61.—Sowing Fiddle

Cuttings. — A very large number of plants may be raised by means of cuttings of the stems or shoots. Soft-wooded or herbaceous cuttings having leaves are used in many cases, the shoots being in a half-ripened condition, that is, neither too young and sappy on the one hand nor too old, dry, and woody on the other. Such cuttings, according to the hardy or tender nature of the plant, are usually inserted in sandy or gritty soil, and most of the leaves are stripped off to check evaporation of moisture from the tissues through the stomata or breathing pores. One, two, three or more leaves are retained, according to the nature of the plant, so that a certain amount of assimilation may be carried on and induce a "callus" to develop over the base of the cutting. Once the callus is formed from the coagulated sap, roots are soon emitted, and the cutting then becomes an established and independent plant. As a rule, stem cuttings are cut immediately beneath a joint, because at that point the fibrovascular bundles containing starchy food matters are closer together, and the callus forms more quickly from the descending sap.

While the cuttings of some plants (e.g. shrubby Calceolarias, Pentstemons, Snapdragons, Phloxes, &c.) root freely in cold frames, others require warmer and more genial surroundings, and must be placed in a hotbed or propagating frame with bottom heat. Indeed, even with hardy plants, the application of bottom heat will often induce cuttings to "strike" or root more readily than they would in cooler surroundings.

Fig. 62.—Begonia Gloire de Lorraine: Stem Cutting

In some cases (e.g. Heaths, Epacris) great care is exercised to encourage roots to develop. The pots or pans in which the cuttings are to be inserted are carefully drained with clean crocks to within an inch or so of the rim, and a compost consisting of 1 part peat and 3 parts silver sand is used for the cuttings. Glasses are placed over them for some weeks, to keep a moist atmosphere around them, and each day superfluous moisture is wiped from the glasses to prevent injurious dripping on the cuttings. The cuttings of such plants as Zonal Pelargoniums, Fuchsias, Calceolarias, Dahlias, Begonias (fig. 62), Phloxes, Pentstemons, Snapdragons, Carnations, Pinks, Lobelias, Aucubas, Roses, Heliotropes, Euonymus, Golden Privet, Skimmias, and many others root readily in any ordinary garden compost of a somewhat gritty nature if kept shaded from brilliant sunshine, and occasionally sprinkled overhead when there is a tendency for the air to become too dry.

Fig. 63.—Shoot of *Skimmia japonica* Rooting

Woody Cuttings.—Many hardy trees and shrubs may be raised from leafless cuttings of the well-ripened young shoots. The best time to take these cuttings is about the end of October and during November, although many will also root freely if taken in spring just when the sap is beginning to rise. With hard-wooded cuttings the basal half, being the ripest or most mature, makes the best cutting, and if taken with a "heel" of the older wood attached it is almost certain to root. The cuttings vary from 1 in. or more to 1 ft. in length, and the larger ones may be inserted about three-fourths of their length in the soil when placed out-of-doors. In this way such plants as Gooseberries, Currants, Roses and Rose stocks like the Brier and the Manetti, Dogwoods, Brooms, Cotoneasters, Diervillas (Weigela), Forsythia, Jasmines, Kerria, Mock Orange (Philadelphus), Flowering Currant (*Ribes san-*

guineum), Willows, Shrubby Spiræas, Tamarisk, Skimmias (fig. 63), and many others, are readily raised.

While small herbaceous and leafy cuttings are inserted with a dibber, which is used for making a hole and packing the soil round the base, long woody cuttings are inserted in trenches made with the spade, or they may be inserted with a dibber. In the first case a line is stretched the length of the row, and a trench with a vertical side is made with the spade. The cuttings are then placed against the vertical side of the trench and pushed into the soil, the distance between the cuttings being about 3 or 4 in. The soil is placed against them and trodden down firmly with the feet, being afterwards levelled. When several rows of hard-wooded cuttings are to be inserted, about 1 ft. is left between the rows, to allow room for weeding and hoeing during the season of growth.

Fig. 64.—Leaf Cutting of Begonia Gloire de Lorraine

A shows old leaf from base of which new plant is arising.

Vines may be raised from cuttings inserted in the open air in the way indicated. As a rule, however, they are raised from single eyes inserted in small pots in heat. Clematises may also be raised from cuttings in the same way. With some evergreens, like Aucubas, quite large pieces of a plant having several leafy branches will root readily if placed in coconut fibre or leaf mould with a little bottom heat.

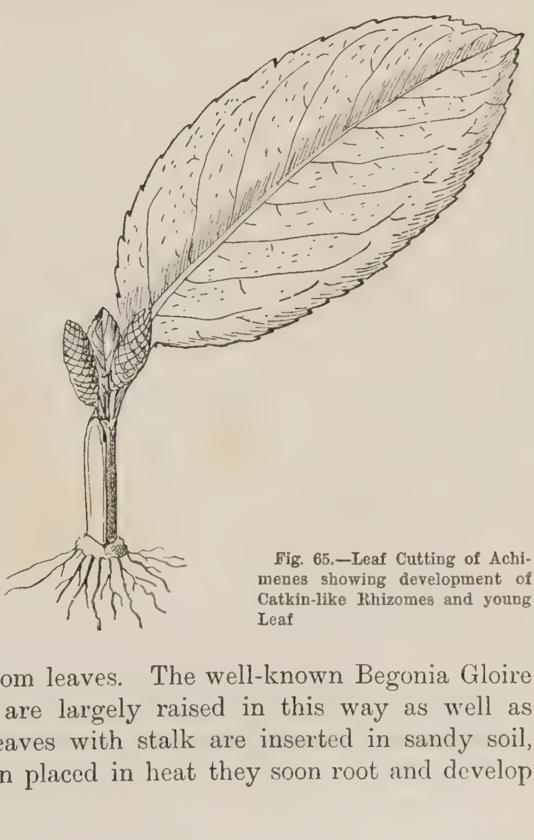


Fig. 65.—Leaf Cutting of Achimenes showing development of Catkin-like Rhizomes and young Leaf

Leaf Cuttings. — Many plants may be raised simply from leaves. The well-known Begonia Gloire de Lorraine and its relatives are largely raised in this way as well as from stem cuttings. Single leaves with stalk are inserted in sandy soil, several in a pot or pan. When placed in heat they soon root and develop

young plants from the top of the leaf stalk, as shown in the sketch (fig. 64). Achimenes are also raised extensively in this way (fig. 65), as are also Gloxinias, foliage and other Begonias, Echeverias, Kleinias, Crassulas, Pachyphytons, &c. In the case of Gloxinias and foliage Begonias the leaves are laid flat on the soil, and have slits made across the midrib and main veins with a sharp knife. They are kept in position by small stones or pieces of broken pot, and kept moist and warm, and soon develop little plants from the slits. In the case of the Indiarubber plant (*Ficus elastica*), while the single leaves will develop roots, as shown in the sketch (fig. 66), and remain fresh for many months, they seem to be incapable of developing plants.

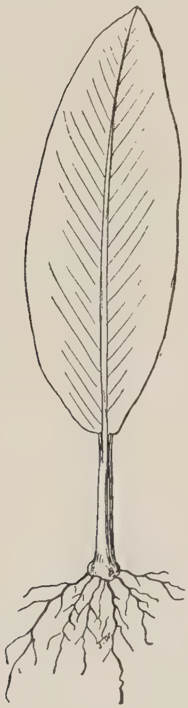


Fig. 66.—Leaf of India-rubber Plant (*Ficus elastica*) Rooting

Fig. 67.—Offsets from a Stonecrop (*Sedum dasyphyllum*)

1, Entire plant, nat. size. 2, 3, 4, Offsets at different levels on the stem in the axils of the leaves. 5, Offsets from floral region.

The thick scaly leaves from the bulbs of many Liliums, if inserted in sandy soil, will produce little bulbs at the base, and these in the course of two, three, or four years will attain the flowering stage. Echeverias are readily propagated in the same way, the detached matured leaves giving rise to plants in due course. Many other fleshy plants may be increased from their leaves, as shown in the annexed cut of *Sedum dasyphyllum* (fig. 67).

Some Orchids (e.g. *Thunia Marshalliana*) may be raised from stem cuttings, as shown in the annexed drawing (fig. 68). The stems of *Ficus elastica*, cut up into pieces each containing one leaf and an eye, root readily in a temperature of 75° to 80° F. Dracæna stems cut up in the same way but without leaves, also root freely, and produce plants when buried

about 1 in. deep in a hotbed of coconut fibre. The tops of Crotons, Dracænas, Araucarias, Aralia Sieboldi, and others also root when inserted in a similar hotbed.

Ringing.—This method of propagation may be called overhead layering. It consists in making an upward or circular slit in the stem of a plant that has become too tall or leggy. Some sphagnum moss and leaf mould is then tied round the wound, and is kept damp with the syringe every day. In a short time the elaborated descending sap from the leaves develops a callus and a mass of roots through the moss. When a sufficient number of roots has been produced, the rooted head is severed and potted up. In this way tall Dracænas, Crotons, Cordylines, Aralias, *Ficus elastica*, American Carnations, &c., may be propagated, as well as by other methods mentioned. If considered worth while, trees with branches too far from the ground might be propagated in this way, but the trouble would be to maintain moisture round the ringed portion. The sketch (fig. 69) shows how this method of propagation may be adopted for trees and shrubs, using a pot with a slit in one side for the purpose.

Fig. 68.—Stem Cutting of *Thunia Marshalliana*

A, Old stem showing fibres from joints. B, Young shoot with roots at base (½ nat. size).

Fig. 69.—Aerial Layering

Root Cuttings.—By cutting up the roots of certain plants into pieces 2 or 3 in. long, and covering them with about 1 in. of gritty soil, it is possible to raise new plants. This method of propagation may be practised about October and November, or in February and March, the root

cuttings being inserted in a hotbed of moderate temperature. Some plants like Horse-radish and Sea-kale are easily and generally raised in this way; while such weeds as the Bearbind, Dock, Thistle, Dandelion are also increased quite as readily by chopping up the roots. Other plants that may be raised by means of root cuttings are *Anemone japonica, Acanthus mollis, Bocconia, Dictamnus Fraxinella,* the Sea Hollies (Eryngium), the Globe Thistle (Echinops), the Oriental Poppy (*Papaver orientale*), *Statice latifolia,* &c. Many kinds of trees and shrubs like Hawthorns, Plums, Apples, Pears, Quinces, Roses, Poplar, Mulberries, False Acacias (Robinia), Sumach (Rhus), Paulownia, Sophora, &c., may be propagated from root cuttings.

Layering.—This method of propagation consists in making an incision in a branch or shoot, and then bending it down and covering with soil. Border Carnations are usually propagated by layering. In the open air the work is done about the end of July and during August. Non-flowering shoots are slit upwards with a sharp knife in a fairly well-ripened portion, thus forming a "tongue". The layered shoots are pegged into the soil with hairpins or pieces of bent wire, and are covered with a nice gritty soil, and given a good watering. At the end of three or four weeks a mass of fibrous roots are emitted from the callused surface of the tongue. Each rooted layer may then be severed from the parent plant which has been feeding it, and may be planted out at once, or potted up to be kept in cold frames during the winter.

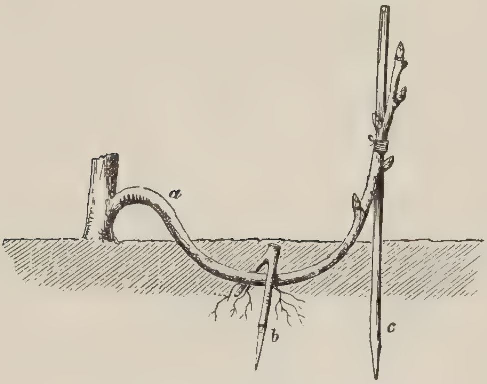


Fig. 70.—Layering a Woody Shoot

In the case of American or Perpetual-flowering Carnations the shoots may be layered whenever they are sufficiently ripe; but it is found more convenient, as a rule, to raise them by cuttings, or by "ringing".

Many trees and shrubs are propagated by layers when they cannot be raised in any other way, or when they are raised most quickly by that method. The young shoots near the ground are bent down and covered with soil, being kept in position by means of bent wires or wooden crooks. Some plants root readily from the joints without any incisions being made, but others are slit in the same way as Carnations, care being taken to keep the tongue open or away from the shoot. In fig. 70 a shoot *a* is shown pegged down at *b*, while a stake *c* is placed to the aerial portion to keep it erect. In fig. 71 the tongue of the shoot is shown at *b*, while another method is shown on the right at *f*, where a ring of bark is taken off the wood. It will be noticed that all

buds are rubbed off on the portion of stem beneath the soil, while they are retained on the overground portions shown at 1, 2, and *h*. Many fruit-tree stocks, like the Crab and Paradise for Apples, Mussel and Brussel Plums, Pears and Quinces, the Mahaleb Cherry, are usually raised from layers, as are also many ornamental shrubs like Magnolias, Cratægus, Osmanthus, Phillyrea, Viburnum, Hamamelis, &c.

In the case of such plants as Vines, Clematis, Wistaria, Lapagerias, and others with long flexuous shoots, the latter are bent down at intervals of a foot or two, as shown in the sketch (fig. 72), the portions *e* being pegged down and covered with soil *b*, the overground portions *d* being furnished with buds. Owing to the snake-like arrangement of the shoots this system of layering is known as "serpentine".

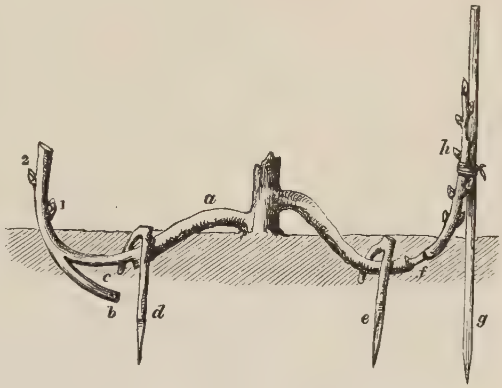


Fig. 71.—Layering by Tongueing and Ringing

Many plants like Gooseberries, Black Currants, Loganberries, and Blackberries, &c., layer themselves naturally when the stems are allowed to lie upon the ground, and they may be propagated in this way if necessary. Many other woody plants could also be propagated by layering if necessary or desirable.

Runners.—A runner is a slender whip-like shoot sent out from the parent plant to root at some distance away, and at certain intervals to produce fresh plants. The Strawberry is the best-known example of a runner-bearing plant, and gardeners readily seize upon this character to raise thousands every year. New varieties of Strawberries, of course, are only obtained from seeds after a more or less lengthy process of cross-fertilizing and selection; but, once established, new varieties are also propagated from runners. Other plants besides the Strawberry throw out "runners" or "stolons", examples of which are met with in the Sweet Violet, the Houseleek, some Saxifrages (like *S. sarmentosa*), and these may be used for propagating purposes. In the case of Couch Grass the underground stolons are produced with more than desirable frequency and pertinacity from the cultivator's point of view.

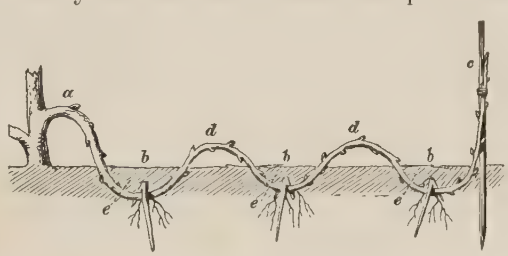


Fig. 72.—Serpentine Layering

Suckers.—A sucker is an aerial shoot springing from an underground stem or root. Suckers usually have some fibrous roots attached to them,

and when severed from the parent may be regarded almost as established plants. Such plants as Chrysanthemums, Plums, Black Currants, Raspberries, Blackberries, Loganberries, produce suckers freely, and may be propagated by them. In the case of Apples, Plums, Peaches, Nectarines, Roses, &c., any suckers arising are, of course, from the wild stocks, and are detached as early as possible, unless they are required later on to form stocks themselves.

Offsets.—Most true bulbous plants, like Tulips, Daffodils and Narcissi, Hyacinths, Liliums, Snowdrops, &c., produce offsets from the parent bulbs. When the offsets are detached and replanted they produce flowering plants the following season, or a season or two afterwards. If some bulbous plants—e.g. Daffodils and Snowdrops—are left undisturbed for years they increase rapidly and produce numerous bulbs. Nerines, Vallotas, Hippeastrums, Crinums, Pancratiums, &c., also develop numerous offsets from the base of the older bulbs.

Corms as produced by Gladioli, Montbretias, Crocuses, Colchicums, are known as "solid" bulbs—as they have no coats as in Tulips and Daffodils or thick scaly leaves as in Liliums. They produce numerous offsets, but the old corm always shrivels up or vanishes while the new ones are forming on top. In such corms as those of the florists' Gladioli (Brenchleyensis, Childsi, Lemoinei, and Nanceianus) numerous seed-like outgrowths are also to be seen. These are known as "spawn" and will produce new plants in a year or two if sown like seeds in nice gritty soil.

In the case of tuberous plants like the Arum Lily, Jerusalem Artichoke, the Potato, the Dahlia, &c., large numbers of tubers or tuberous roots are produced, each one of which will give rise to one or more plants. The tubers of the Artichoke and Potato, for example, if cut into pieces each containing an "eye" or bud, will produce several plants. The tuberous roots of the Dahlia and the herbaceous Pæony, however, must have a piece of the old stem attached, as no shoots are produced by the roots themselves. The tubers of Begonias, Cyclamen, and Gloxinias may be cut into pieces each with an eye or sprout.

Underground stems or rhizomes, as met with in the German, Florentine, and other Irises, Solomon's Seal, Mint, &c., are utilized for increasing the stock, each portion having a bud being capable of forming a new plant.

Bulbils.—Many bulbous plants like *Lilium bulbiferum* and others produce seedlike bodies known as "bulbils" in the axils of the aerial leaves. These bulbils are capable of producing plants if sown in suitable soil and grown on for a year or two. (See fig. 24, p. 39.)

In some Ferns, e.g. *Asplenium bulbiferum, A. biforme, Woodwardia radicans*, little plants also called "bulbils" appear on the fronds, and from these large numbers of plants may be raised quickly without having recourse to sowing spores. These bulbils may be regarded in the light of aerial offsets. (See fig. 46, p. 59.)

Division of the Rootstock.—A very large number of herbaceous perennials, both hardy and tender, are more readily increased by splitting

up or dividing the tufts into several portions, each containing a supply of roots. This operation is done either in the spring or in the autumn. If plants flower naturally during the spring and summer months they are usually best divided in the autumn; but if they flower in late summer and autumn they are generally best divided in the spring. Circumstances, however, may necessitate plants being divided at any season if it is desired to raise stock quickly without risking the life of the plants. Many plants that do not produce seeds or spores can only be propagated by division. Many Orchids, Ferns (e.g. *Adiantum Farleyense*, and Nephrolepis), and Bamboos are raised in this way, as it is the only one possible.

Budding.—The art of budding consists in removing a bud from one plant and inserting it partly beneath the bark in another growing plant in such a way that it will obtain nourishment from its host, and eventually bear flowers or fruits. In the open air budding is generally practised from the end of July and during August, but may be done as late as September under abnormal circumstances, such as a particularly hot and dry season, when the sap may not flow freely until the weather becomes cooler, or until rain falls. Under glass, budding may be practised almost at any season when the buds and stocks are in a sufficiently advanced condition, but from January to March is the usual time. Only dicotyledonous plants can be budded or grafted, because they possess a cambium (see p. 36), and it is essential also that the bud or graft and the stock should be in the same family and closely related. Otherwise the difference in constitution and nature might be so great that union would be impossible. Thus Roses are budded on Brier or Manetti Rose stocks; Apples on Crab-apple, Paradise, Doucin, or free stocks; Pears on Pear or Quince stocks; Plums, Peaches, Nectarines, Apricots, Cherries on Plum stocks, and so on with other groups of plants (fig. 73).

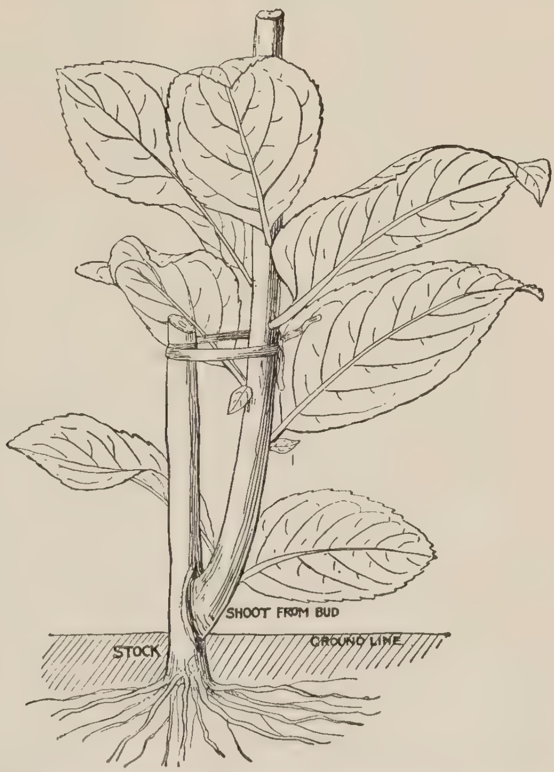


Fig. 73.—Shoot of Apple arising from Bud inserted in Stock close to Ground Line, the Stock being cut back to form a stake to which young shoots are tied

The bud or graft is really a kind of parasite. The plant that springs from it has no roots of its own. It is dependent upon the roots of the stock for the crude sap, which is pumped up into its stems and leaves from the soil. This crude sap, however, is elaborated in the leaves of the scion, and not in those of the stock; hence the changes are such that the leaves, flowers, and fruits exhibit the features and usually possess the nature of the scion and not of the stock, *Laburnum adami* being a notable exception.

There are several ways in which buds may be inserted, but the best and commonest method is that known as shield budding or T budding (fig. 74). The dormant buds are taken from a ripened shoot of the current year's growth, each bud having a small piece of leaf stalk attached to serve as a handle. The stocks in which the buds are to be inserted in July and August should have been planted the previous October or November to get them well established by then. Buds are either inserted as low down the stem and as near the root as possible, or they may be inserted on the topmost shoots of a stock 3 to 10 ft. high. In either case a transverse slit is made with a sharp budding knife, and an upper cut about 1 in. long is made to meet it, the two cuts forming the letter T. The flat bone handle of the knife is gently pushed in the upper slit to open the bark, and render it easy to insert the bud, which has been severed in advance and placed between the lips while the slits were being made. In taking a bud the chief point is to select one that is dormant, and neither too young near the top of the shoot, nor too old or sprouting from near the base. If a flat piece of wood is taken off with the shield of bark it should be removed, care, however, being taken not to tear out the body of the bud with it. Some Continental and American budders do not trouble to detach the piece of wood, but in British gardens it is customary to do so. The bud being inserted, the bark is then tied round it with raffia or worsted thread, carefully but firmly, to exclude the air. In two or three weeks the bud will have united with the stock, and it will be necessary to cut the tying material. An expert budder will bud from 500 to 700 stocks per day, or more, with the assistance of an intelligent lad to clean the stocks and tie the buds after insertion.

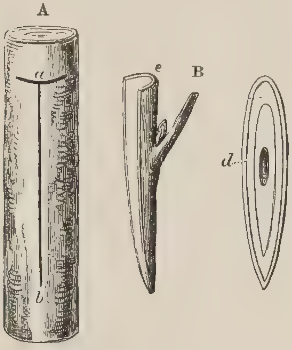


Fig. 74.—Showing Stock A, with T-cut at *a* for reception of Bud B, side view of which is given at *e*, and inner face view at *d*

Grafting.—Unlike budding, where a single bud is used, grafting consists in affixing a shoot of one plant with two or more buds on to the stem of another in such a way that the cambium layer of one must come face to face with that of the other. The shoot is called the "scion", and the plant on which it is placed is called the "stock"—the latter being already well rooted and established for twelve or eighteen months in advance to ensure complete success. As in budding, so with grafting—the stock and scion must be closely related, and belong at least to the same natural

family. There are several ways in which grafting may be done, and the principal ones will be mentioned.

Whip Grafting.—This is the best method when the stock and scion (or graft) are nearly of the same thickness, and thousands of fruit trees are propagated in this way every March and April in the open air. Preparatory to grafting taking place the stock is usually "headed" back in January or February; that is, the stem is cut off, leaving a stump a few inches high sticking out of the ground. The cut surface soon heals, as little or no sap is rising at that cold period of the year. The grafts or scions, which always consist of ripened one-year-old shoots, are also severed about the end of January or February, and are "heeled in" in bundles under a north wall. This prevents them starting into growth prematurely, and keeps the sap in them in a less active condition than if the shoots were allowed to remain on the parent plant.

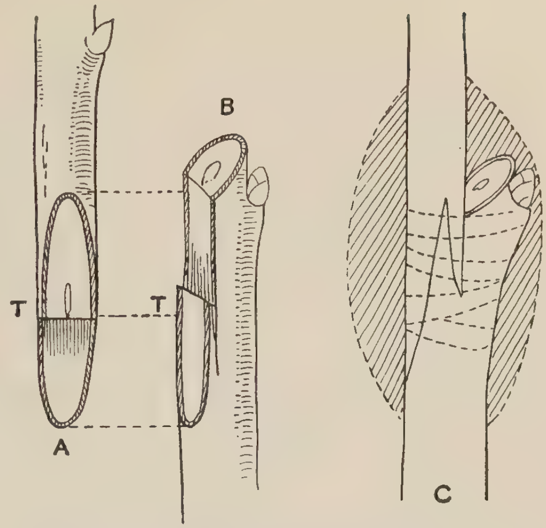


Fig. 75.—A Graft or Scion A, cut and tongued at T to fit top of Stock B; at C is shown the Graft and Stock united, tied, and waxed or clayed

The grafting period in the open air being reached, that is, in March and April, a slanting cut is made in the stock as shown in fig. 75, and a nick is made in it to form a tongue. The graft or scion, having two or three buds attached, is also cut obliquely, as shown in the figure, and a tongue is also made in it so that it shall fit into the one made in the stock. The two cut surfaces should be about the same length and width if possible, but it is not essential. One edge of the scion, however, must be made to fit flush with the edge of the stock, to bring the cambium layer of each face to face, because it is by means of the new cells


Fig. 76.—Showing how Badly Treated Young Fruit Trees are grafted in some Market Gardens

from the cambium that union is to take place. The graft being properly fitted to the stock it is then tied round securely with raffia, or matting, or worsted thread, after which the joint is covered over completely with grafting wax, or clay made into "pug" by mixing it with a little chopped hay or straw. A good grafting wax may be made by boiling in a saucepan some beeswax, resin, and Russian tallow in equal proportions. While still warm (not hot) this mixture, which should be of the consistence of treacle, is easily applied with a little brush or flat piece of wood. A rough-and-ready method of grafting as practised in some market gardens is shown in fig. 76, taken from an actual specimen.

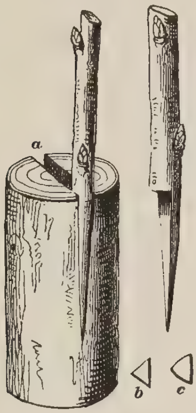


Fig. 77.—Cleft Grafting

Cleft and Rind Grafting.—In the case of old t.ees, having the stems many times thicker than the scions, whip grafting could not be conveniently done. The stocks are headed back at the proper season, and at the proper time a slit is made in the bark with a strong-bladed knife, or a cleft is made with a chisel, as shown in fig. 77 at *a*. The latter is not a good way to graft, as it leaves a fissure open in the stem, in which water collects and rots the wood later on. The slit with the knife is best, and the bark may be gently opened outwards with the point of a small chisel or flat piece of steel to allow the graft, which has been cut obliquely to form a wedge, to be pushed in easily. Two or three similar grafts may be inserted in one stem if necessary, and if the bark only is open, without splitting the wood, the process is known as "rind" or "crown" grafting, as shown in fig. 78.

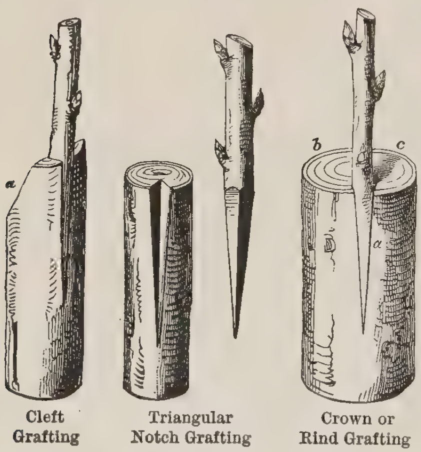


Fig. 78.—Forms of Grafting

Saddle Grafting.—When the stock and scion are about equal in diameter this method may be adopted, but it is not so good as whip grafting and is also more troublesome to perform. As shown in fig. 79, the stock A is cut up on both sides to form a wedge ending at *c*. The graft or scion B, having several buds, is split up the centre, and each half is thinned to make it fit astride the tapering stock, and so that the inner bark of stock and scion are flush with each other at least on one side.

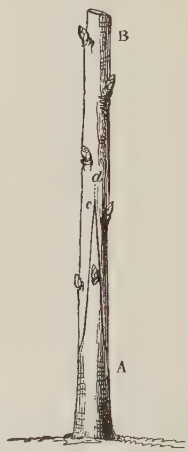


Fig. 79.—Saddle Grafting

Side Grafting.—This is a form of whip grafting, but the stem is not cut away completely above the point of union. A notch or slit is made in the side of the stock, as shown in fig. 80 at *a*, *b*, and the scions are inserted and tied. It will be noticed that horizontal or vertical shoots may be grafted in this way, and after the new shoot has grown to a good length the stocks may be cut off just above the point of union.

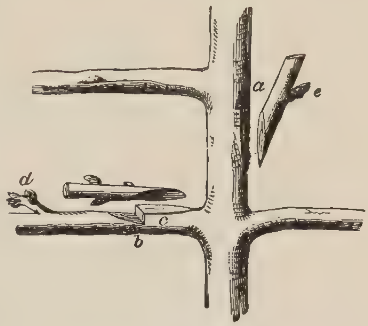


Fig. 80.—Side Grafting

Herbaceous Grafting.—This is applicable to plants having non-woody stems, and is practised only for the sake of curiosity. Potatoes have been grafted on Tomatoes, and vice versa; Cauliflowers on Cabbages; Zonal Pelargoniums, Dahlias, &c. It seems, however, to be of real value in the Australian Glory Pea (*Clianthus Dampieri*), which grows freely when grafted on the stems of seedling *Colutea arborescens*, but will often perish on its own roots.

Coniferous trees have been grafted with young shoots in the forest of Fontainebleau and other places, the *modus operandi*, as described by Du Breuil, being as follows: "When the terminal shoot of the stock *a* (fig. 81) has attained about two-thirds of its length, it is cut back with a horizontal cut to the point where it begins to lose its herbaceous consistence and commences to become woody. The young leaves are cut off between *a* and *d*, a distance of between 2½ and 3 in., leaving, however, about two pairs at the top *d d*, to attract the sap. Thus prepared, the stock is split down the middle to the depth of 1 in. or 1½ in. The scion *b* is cut wedge-shaped, and introduced into the split, so that the commencement of the cuts on each side of the scion may be nearly 1 in. below the top of the stock. The scion should be cut at the place where its consistence is similar to the part of the stock where it is to be inserted. Its diameter ought to be as nearly as possible equal to that of the stock. The graft being placed, it is secured with coarse worsted, commencing the tying at the top and winding it down to the lower part. In the case of delicate species it is well to wrap paper round the grafted part as a protection against the drying action of the sun and air. The shoots at *c* are then broken at about ½ in. from their bases. Five or six weeks after grafting, the cuts will be completely healed; the tie may then be removed, and the two portions *d* furnished with leaves at the top of the stock should be cut off, otherwise they might give rise to buds, which, in pushing, would weaken the graft."

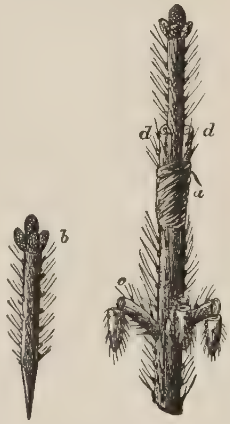


Fig. 81.—Herbaceous Grafting—Coniferous Trees

Root Grafting.—Many plants are propagated by inserting a short shoot in a root of a relative or by side grafting. Most of the Tree Pæonies are raised by inserting a shoot in a cleft of a tuberous root of *Pæonia officinalis*, making the edges fit flush on one side, and then tying them up with raffia, &c. Shoots of Wistaria are also inserted in the fleshy roots of the same plant, as shown in fig. 82, while garden varieties of Clematis are grafted in thousands on the roots of the common *C. Vitalba*.

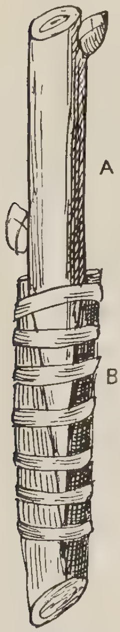


Fig. 82.—Root Grafting Wistaria

A, Shoot inserted in root B and tied.

Inarching or Grafting by Approach.—This method of propagation was, no doubt, suggested originally by the fact that boughs of trees that rub against each other and wear away the bark become united later on by means of their cambium layers. Inarching is thus a kind of grafting, but differs in that each of the plants to be united is growing on its own roots. It is often practised on Vines. A shoot of a desirable variety is cut and tongued on one side to fit into a similar cut and tongue on the undesirable one that may be worth retaining on account of its state of development, and to avoid replanting and remaking of the borders. When the inarched shoot has become firmly united it is severed from its own feeding base, while the stock to which it is attached has the portion above the inarched scion also cut away, thus leaving the lower portion of the stem and the roots. In this way a new variety takes the place of the old one without much trouble.

Bottle grafting is a form of inarching, and has been practised in connection with Oranges, Vines, Oleanders, and other woody-stemmed plants. A ripened shoot is taken, say of a Vine, about 1 ft. long. It is cut about 4 or 5 in. long, and tongued on one side about the middle, to fit into a corresponding cut and tongue on the stock. It is tied on securely, but the base of the shoot is stuck into a bottle of water. The latter should be replenished from time to time, fresh rainwater being preferred, and a few lumps of charcoal may be put in to keep it fresh for a longer period. [J. W.]

SECTION IV

The Science of the Soil

§ 1. INTRODUCTORY

When a man intends to grow fruits, flowers, or vegetables for profit his first consideration is the "soil". This constitutes his chief raw material, and he knows that if he makes a mistake in its selection it may lead him to ruin, or become such a drain upon his resources and labour that his life becomes one of drudgery, anxiety, and worry.

In these days there is a danger of a good cultivator ignoring the teachings of his own practical experience, and trusting blindly and implicitly to the dicta of the botanist and chemist, and others whose acquaintance with the actual cultivation of plants may be of the slightest. A man may be told that a certain soil contains enough plant food to last a thousand years, and an elaborate analysis of the phosphates, potash, iron, magnesia, soda, lime, and other essential plant foods will be produced in support of the statement. From a purely theoretical point of view such a statement may be chemically correct, but the said foods may be locked up or combined in such a way in the soil that it would take generations of hard work and a mint of money to bring them into anything like an available condition.

While it would not be wise to ignore the chemical analysis of a soil altogether, the intelligent cultivator will not rely entirely upon it. He will use his own judgment, the value of which will of course depend largely upon his practical experience and observation. He will find a safer guide than mere chemical analysis in examining carefully the vegetation of any piece of land he contemplates cultivating. Here his knowledge of plants, their relationship to each other, and the natural conditions that suit them will be of great value to him.

> "Nor every plant on every soil will grow:
> The Sallow loves the watery ground, and low;
> The marshes, Alders: Nature seems to ordain
> The rocky cliff for the Wild Ash's reign;
> The baleful Yew to northern blasts assigns,
> To shores the Myrtles, and to mounts the Vines."

On *poor, sandy,* or *gravelly soils,* for instance, he will notice such plants

growing as the Lesser Bindweed (*Convolvulus arvensis*), the Musk Mallow (*Malva moschata*), the Hairy Cinquefoil (*Potentilla argentea*), the Gallic Catchfly (*Silene gallica*), the Speedwell (*Veronica officinalis*), the Hawkweed (*Hieracium Pilosella*), Chamomile (*Anthemis nobilis*), Shepherd's Purse (*Capsella Bursa-pastoris*), Corn Bluebottle (*Centaurea Cyanus*), Poppy (*Papaver Rhœas*), Heather (*Calluna vulgaris*), Spanish Broom (*Cytisus scoparius*), Bracken (*Pteris aquilina*), Sterile Brome Grass (*Bromus sterilis*), &c.

On *wet* or *marshy soils* the following weeds may be found: Dog's Bent Grass (*Agrostis canina*), Cuckoo Flower (*Cardamine pratensis*), Marsh Thistle (*Cnicus palustris*), Horsetail (*Equisetum arvense*), the Marsh Galium (*Galium palustre*), Corn Spurrey (*Spergula arvensis*), Comfrey (*Symphytum officinale*), Flowering Rush (*Butomus umbellatus*), Bulrush (*Typha latifolia, T. angustifolia*), Forget-me-Not (*Myosotis palustris*), Rushes (*Juncus* spp.), Sedges (*Cyperus* spp.), Loose-strife (*Lythrum Salicaria*), Willow Herb (*Epilobium*), Common Carrot (*Daucus Carota*), Butterbur (*Petasites vulgaris*), Water Ragwort (*Senecio aquaticus*), Yellow Meadow Rue (*Thalictrum flavum*), Ivy-leaved Crowfoot (*Ranunculus hederaceus*), Great Spearwort (*Ranunculus Lingua*), the Lesser Spearwort (*R. Flammula*), the Marsh Marigold (*Caltha palustris*), Watercress (*Nasturtium officinale*), Sundew (*Drosera*), Mare's Tail (*Hippuris vulgaris*), Water Milfoil (*Myriophyllum*), Pennywort (*Hydrocotyle vulgaris*), Water Parsnip (*Sium*), Valerian or All Heal (*Valeriana*), Bur Marigold (*Bidens cernua*), &c.

On *chalky* or *limestone soils*: the Pasque Flower (*Anemone Pulsatilla*), the Stinking Hellebore or Setter Wort (*Helleborus fœtidus*), the Baneberry or Herb Christopher (*Actœa spicata*), Whitlow Grass (*Draba muralis*), Penny Cress (*Thlaspi perfoliatum*), Cheddar Pink (*Dianthus cœsius*), Goldilocks (*Aster Linosyris*), the Fetid Hawk's Beard (*Crepis fœtida*), Wild Sainfoin (*Onobrychis sativa*), Chicory (*Cichorium Intybus*), Fumitory (*Fumaria officinalis*), Bladder Campion (*Silene inflata*), &c.

On *clayey soil* or very heavy loam will be found Docks (*Rumex*), Coltsfoot (*Tussilago Farfara*), Creeping Bent Grass (*Agrostis repens*), Floating Foxtail Grass (*Alopecurus geniculatus*), Sow Thistle (*Sonchus arvensis*), Rest Harrow *Ononis spinosa*.

Where, however, one notices the Hawthorn hedges, Wild Plums and Sloes, the Elms, Oaks, Beeches, Ashes, and Lime trees growing luxuriantly, the soil bearing them, or adjacent, may be looked upon as the best for general gardening or farming. It contains a fair mixture of sand, clay, lime, and decayed organic matter (humus), and such a soil is likely to yield the best results—if it is properly cultivated, but not otherwise. The following weeds also indicate a good loamy soil suitable for the cultivation of Fruits, Flowers, and Vegetables, viz.: Thistles, Stinging Nettles, Groundsel (*Senecio vulgaris*), Goosefoot or Fat Hen (*Chenopodium album*), Annual Sow Thistle (*Sonchus oleraceus*), Dandelion (*Taraxacum officinale*), Chickweed (*Stellaria media*), &c.

§ 2. CLASSIFICATION OF SOILS

Soils are classified in various ways, according to their texture and mechanical composition. Thus such terms as poor, hungry, cold, hot, wet, heavy, light, sour, sweet, are used to denote various conditions; while the terms sandy, clayey, loamy, chalky, marly, and peaty indicate the predominating constituent of a particular soil.

Several of these terms really mean the same thing to the cultivator. A poor, hungry, light, or hot soil, as a rule, indicates one of a sandy or gravelly nature. Such a soil is "poor" because it is impoverished of plant foods; it is "hungry" because it eats up enormous quantities of organic manures; it is "light", not because of its actual weight, but because it crumbles and falls to pieces easily, and its particles will not cohere and retain sufficient moisture or food; it is "hot" because its gritty particles absorb so much heat during the day that moisture is driven away from the roots of the crops. A "hot" soil also has great variations and fluctuations of temperature, being generally too hot by day in the summer and too cold by night in winter. A hot soil, however, that is well manured and supplied with sufficient moisture is valuable for the production of early crops.

On the other hand, a cold, wet, heavy soil usually denotes one of an ill-tilled, clayey nature. Such a clayey soil is "cold" because of its "wetness", the heat of the sun being used to dry up the superfluous water instead of being available to warm the soil particles and promote root action. It thus follows that a wet and cold soil is also a "heavy" one, that is, one very difficult to lift, owing to the cohesiveness of its particles, and not so much on account of its actual weight.

When a cold, wet, and heavy, clayey soil is also full of decaying organic material, and is never deeply cultivated, it then becomes "sour". This sourness is due to the fermentation and decomposition of the organic refuse, which liberates the carbonic acid gas so freely that oxygen is driven out of the soil. A good loamy soil even may be brought into a sour condition by overdressing with stable manure, and by not digging deeply to allow the fresher air to enter and the water to pass away freely to the lower strata.

To test a soil for sourness or acidity, place a small portion into a clean Florence flask, adding enough distilled or filtered rain water to cover it. Boil over a lamp for about fifteen minutes, afterwards allowing the solid matters to settle. Then pour off the clear liquid, and test with a slip of *blue* litmus paper. If the paper turns red, it is a sign that the soil is sour. To remove the acidity, the soil should be deeply dug, and lime or basic slag added.

It may be well to say something as to the peculiarities of sand, clay, loam, chalk, lime, peat, and humus.

Sand.—Sand consists of small pieces of hard rock that have been broken down into various degrees of fineness or coarseness from such

rocks as silica or flint, sandstone, quartz, granite, &c., by the action of the weather and water. The peculiarities of sand are: it is hard and gritty; it will not float in water; its particles will not cohere readily even when wet, nor can they be moulded into any shape for any length of time; it will not hold water; it absorbs and radiates heat readily; and in a fine condition its particles are blown about easily by the wind when dry.

When mixed with clay, peat, loam, and other soils sand is useful because it renders the soil more porous, warmer, easier to work, and better aerated—all valuable properties for plant growth.

Clay.—This is also composed of fine particles, but much finer than in sand, and possessing different properties. The particles are soft and greasy to the touch when wet, and can be moulded into any form; they also float in water for a long time and make it "muddy"; they retain moisture for a long time, and will not allow it to escape readily. When dry, clay cracks and shrinks; when wet it expands, and becomes very slippery to the foot.

Clayey soil by itself is fit only for making bricks, pottery, &c., the finest chinaware being made of a whitish clay containing silica, alumina, and water. When burned, clay undergoes marvellous changes. It is no longer sticky, plastic, or impervious to water, and its particles are loose, porous, and brittle. Even when wetted, burned clay can never revert to its original plastic and slippery condition. In some places the clay soil is often burned with the object of making it lighter, warmer, and more porous.

The advantage of clay in a garden soil is that it detains moisture and manures, and prevents the temperature from rising too high in summer and from sinking too low in winter, owing to its poor conductive powers.

Loam.—Sand and clay in about equal proportions, and with a quantity of organic material, constitute a "loamy soil"—the ideal soil for the horticulturist or agriculturist. When a loamy soil contains more sand than clay it is called a "sandy loam"; when more clay than sand, a "clayey loam". The various compositions may be expressed as follows:—

	Per Cent of Sand.	Per Cent of Clay.
Sandy soil contains	80 to 100	20 to 0
Sandy loam "	60 " 80	40 " 20
Loam "	40 " 60	60 " 40
Clayey loam "	20 " 40	80 " 60
Clayey soil "	0 " 20	100 " 80

Chalk.—A chalky soil is one derived from limestone rocks which, when burned, yield the lime of commerce. Lime differs from chalk in not containing carbonic acid gas; this was driven off in the burning. When lime is burned it is known as quicklime; and when water is poured on this it is readily absorbed, expansion takes place, and great heat is generated.

The result is then known as hydrate of lime. When quicklime is exposed for a time to the air, it gradually absorbs carbonic acid gas, and thus reverts to a chalky or carbonate of lime condition.

Chalk or limestone (calcium carbonate) is known to geologists as organic rock, because it is made up of the remains of shells and bones of sea and freshwater fish. This may be seen by rubbing down some fragments in water and examining the dried sediment under the microscope. Minute shells, pieces of coral and sponges, and broken fragments of shells will be observed, as well as the remains of other marine creatures. Limestone hills and rocks are to be found in many parts of the world thousands of feet above sea level, and bear silent testimony to the upheavals that must have taken place on the surface of the globe in past ages. In the same way our coal seams represent ancient forests and fertile vegetation that have become submerged, and afterwards covered with deposits of other layers of soil.

Lime.—Lime, to use the popular term, is a most important ingredient in soils, and may be employed in various forms, such as marl, gypsum, quicklime, chalk, slaked lime, gas lime (or "blue billy"). For a heavy, wet, clayey soil a heavy dressing of quicklime is one of the ways of bringing it into a good state of cultivation. In milder forms of chalk (carbonate of lime) or gypsum (plaster of Paris) it is a valuable adjunct to good garden soils, especially if they have been overdressed with organic manures.

The advantages of adding lime to the soil may be summed up as follows:—

1. It makes a stiff or clayey soil drier and more porous by making the sticky particles coagulate or flocculate, and thus leave passages for the air. This may be proved by putting a little lime into a glass of muddy water. The particles that would otherwise float about for a long time soon come together in flocks and drop to the bottom, leaving the water clear.

2. Lime, being an alkali, is fatal to sourness and acidity in the soil, and renders it "sweet" and favourable to vegetation. Where magnesia is in excess the addition of lime will rectify any ill effects.

3. Without the presence of lime in the soil beneficial micro-organisms would not be generated from the organic constituents, and there would be a lack of nitrogenous food. On the other hand, when a soil has become too rich in nitrogenous foods, that cause luxuriant, sappy, and unproductive growths, the addition of lime will soon restore the balance, although at first giving apparently greater vigour to the shoots.

The presence of lime in any soil may be detected in a simple way. Take a fair sample and place in a glass, and pour over it some fairly strong acid, such as hydrochloric. If lime is present a vigorous fizzing or effervescence will take place; if not, it may be assumed that little or no lime is present and it should be added.

Peat.—This name has been applied to the remains of plants that have accumulated in the course of centuries on the margins of shallow lakes and in marshy land. The lakes or marshes gradually disappear with the encroachment of the vegetation. and the latter becomes pressed down

into more or less solid or spongy fibrous layers of organic material often several feet deep. Wherever natural peat beds exist, they are found on soil or rock that has been hollowed out like a bowl or saucer into which the water from the surrounding land drains and keeps in wet condition for a great portion of the year.

Peat when dry burns readily, and is used in the same way as coal in parts of Ireland and Great Britain. It absorbs water freely and is therefore valuable when mixed with sandy soil. Some plants, like Rhododendrons, Azaleas, Kalmias, Heaths, Andromedas, and many other Ericaceous plants like to have a good deal of peat in their compost; but very few plants would thrive in peat alone.

Humus.—While sand, clay, lime, and peat are all useful and necessary ingredients of every good garden soil, each one by itself would be practically useless. When mixed together in certain proportions they are more valuable, but they still lack something to make them into a really good garden soil. It would be possible, for example, to obtain sand, clay, and limestone from the roadway when excavating for sewers and other purposes. But no one would dream of trying to grow plants upon such material, even if mixed in suitable proportions. There is evidently something lacking, and that something is of an organic, not a mineral, nature.

When the decayed remains of plants and the refuse from animals (including decayed leaves, peat, stable manure, &c.) are mixed with the mineral ingredients it is found that plants grow well. This plant and animal refuse in a thoroughly decomposed condition is known under the name of "humus". One of the most popular forms in which humus is added to the soil is leaf mould or leaf soil. Every crop would produce a large quantity of leaf mould every year, but much valuable material is wasted, and the deficiency must be made up by the purchase of stable and other manures.

The best kind of leaf mould is seen in natural woods of oak, beech, lime, &c., more especially in the ditches and hollows where great accumulations have taken place. Leaf mould is largely used in the cultivation of many kinds of stove, greenhouse, and hardy plants mixed with loam, sand, and peat in various ways. The beds on which the French maraîchers grow their Lettuces, Endives, Carrots, Radishes, Cauliflowers, &c. (see Vol. IV), are almost entirely humus, with a certain amount of inorganic gritty soil; hence the luxuriant and rapid growth that is secured.

Advantages of Humus.—The addition of humus to the soil has physical and chemical effects. Physically humus absorbs and detains moisture; it raises the temperature of the soil and maintains it in an equable condition; it keeps the particles of sand and clay asunder and therefore improves the aeration and porosity; it detains the heat, and thus prevents the roots of plants being frozen during hard frost. But humus performs other important functions in the soil, especially in connection with the nutrition of many trees and shrubs and green-leaved plants generally. It has been discovered that the roots of many plants

(e.g. Oaks, Beeches, Poplars, Elms, Rhododendrons, Cranberries, Bilberries, Brooms, Heaths, Conifers, &c.) are invested with the filaments of certain fungi, which, instead of being injurious, are actually beneficial. These fungal threads are interwoven in the tissues of the feeding roots, and often look like root hairs, and perform similar functions of absorbing water from the soil together with the mineral salts and other compounds dissolved in it. The name of "mycorhiza" has been given to these fungi which envelop the roots of many plants, and it has been proved that they are not only beneficial and essential to the plants on which they grow, but that they can only come into existence when humus is present in the soil. This accounts for the great esteem in which all gardeners hold leaf mould

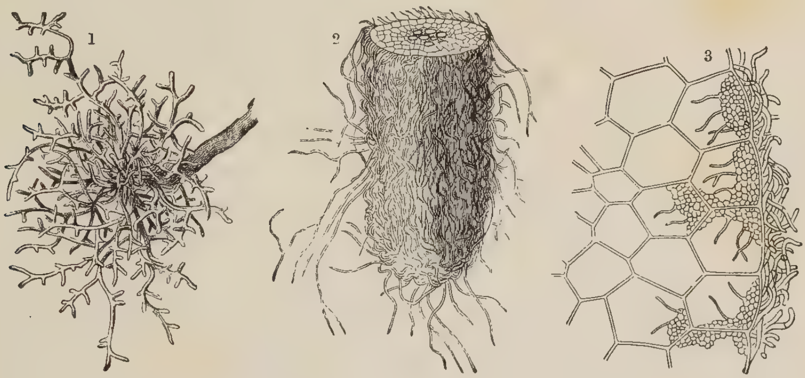


Fig. 83.—1, Roots of White Poplar with mycelial mantle. 2, Tip of Root of Beech with closely adherent mycelial mantle × 100 (after Frank). 3, Section through a piece of wood of the White Poplar with the mycelium entering into the external cells. × 180.

as an ingredient in the soils they use, and they know by actual experience that a soil without humus or leaf mould would be practically useless for their plants (fig. 83).

Chemically, humus gives rise to living micro-organisms in the soil, when lime is present, during the process of fermentation and decay, if the temperature is favourable, and thus yields up a supply of organic food in the process of decomposition.

The following table shows the composition of three different kinds of humus:—

Constituents.	Leaf Mould.	Forest Mould.	Peat Mould.
	per cent.	per cent.	per cent.
Organic matter (humus) ...	17·00	8·46	18·80
Clay and silica (sand)	79·80	63·34	76·05
Nitrogen...	0·50	0·45	1·40
Potash	0·31	0·73	0·31
Phosphoric acid	0·06	0·10	0·20
Lime	0·19	2·08	0·53
Magnesia	...	1·71	...
Soda	...	0·10	...
Monoxide	0·26	4·98	0·20

§ 3. MECHANICAL ANALYSIS OF SOILS

Besides an examination of the natural vegetation referred to at p. 90 the experienced plant-grower will also make a physical or mechanical examination. He will handle the soil, feel its texture, noting its colour and whether its particles cleave together or fall asunder and crumble into dust; and if he is wise he will also have a good-sized hole dug out to a depth of 3 or 4 ft. so that he may see the geological formation. He will then be able to form a good opinion as to what may be done with the land. If the vertical section of the hole shows a good depth of yellow loam resting on sand, gravel, or chalk it is a good sign. Such a soil will contain plenty of plant food, may be easily, deeply, and economically worked, will not require large quantities of manures, will not be too dry or too hot in summer, nor too cold or too wet in winter, and will respond readily to good cultural practice.

It follows that any other soil which does not approach this ideal is less valuable and may cost a good deal more to cultivate.

To gain a fairly accurate idea as to the physical condition of a soil a fair sample of it should be taken from the first, the second, and the third spit down. A cubic foot of each might be taken and weighed. This multiplied by 43,560 will be the weight per acre. A certain quantity of soil, say 10 oz., should be spread out and allowed to dry in the sun and air. Weigh again, to see how much moisture has escaped, and compute the amount per acre. After air-drying and noting the amount of water given off, the samples should then be baked over a fire until all the organic material is driven off by combustion into the atmosphere. In this way the carbon, oxygen, hydrogen, and nitrogen will be liberated, and the residue will represent the mineral substances which cannot be further reduced. Then pass each sample through a sieve with an ⅛-in. or ¼-in. mesh, so as to take out all the larger stones. Weigh these also and compute for the acre. The finer soil left should be mixed with water in a glass vessel and well churned up with a stick; hot water will free the finer particles better from the sand and gravel than cold. All the fine clayey particles will remain suspended in the water and make it muddy, while the sand and grit will fall to the bottom. By pouring off the muddy water time after time, until at last the water is quite clear, the mud or clay will be separated from the sand. Allow to settle, pour the water off carefully, and when sand and clay are dry they can be weighed. The result will show the proportion of each in the sample, and the weight may be computed for the acre.

The weight of a cubic foot of soil of various kinds in a dry and wet state, and the amount of water each contains, have been computed as follows by M'Connell in his *Notebook of Agricultural Facts and Figures*:—

Kind of Soil.	One Cubic Foot Weighs.		Amount of Water in One Cubic Foot of Wet Soil.
	In Air-dry State.	In Wet State.	
	lb.	lb.	lb.
Siliceous sand	111·3	136·1	27·3
Calcareous sand...	113·6	141·3	31·8
Sandy clay	97·8	129·7	38·8
Loamy clay	88·5	124·1	41·4
Pure grey clay	75·2	115·8	48·3
Humus	34·8	81·7	50·1
Garden mould	67·8	102·7	48·4

The mechanical constitution of a good garden soil for the production of most fruits, flowers, and vegetables might be stated thus, and assuming that an acre of soil at 1 ft. deep weighs 3,000,000 lb.:—

Clay,	40 per cent	=	1,200,000 lb.	per acre.
Sand,	35 "	=	1,050,000 "	"
Lime,	10 "	=	300,000 "	"
Humus,	15 "	=	450,000 "	"

These figures may be compared with the following analysis of a fertile soil on the same basis:—

	Per Cent.	Lb. per Acre of 3,000,000 lb.
Potash	1·03	30,000
Soda	1·97	60,000
Ammonia	·06	1,800
Lime	4·09	120,000
Magnesia	·13	3,900
Peroxide of iron	9·04	270,000
Protoxide of iron	·35	10,500
Protoxide of manganese	·29	8,700
Alumina	1·36	40,800
Phosphoric acid	·47	14,100
Sulphuric acid	·90	27,000
Carbonic acid...	6·08	180,000
Chlorine	1·24	37,500
Soluble silica	2·34	70,200
Insoluble silica clay } Insoluble silica sand }	57·65	1,729,520
Organic matter (humus)	12·00	360,000
Water or loss...	1·00	30,000

The grower should avoid a purely sandy or gravelly soil, because it will empty his purse in purchasing manure and supplying water; and he should shun a wet, heavy, sticky yellow clay such as is suitable for the making of bricks and pottery, because it would require large funds

and many years of cultivation to induce such a soil to bear even reasonably good crops. The very worst soils can be brought into a state of fertility in time, but it will never pay the commercial horticulturist to waste his time upon them.

A man need not be a chemist to be able to distinguish the differences between a sandy, loamy, peaty, chalky, or clayey soil, and although each one contains essential plant foods in varying proportions it would be a mistake to assume that they are all equally valuable or available.

These remarks relate chiefly to the soil when it is to be worked in a natural condition by the grower of fruits, flowers, and vegetables in the open air. Although the grower under glass is not hampered so much with the natural soil and the weather, it is nevertheless to his advantage to select the best possible soil on which to erect his glasshouses, especially if he intends to embark on the culture of such crops as Grapes, Tomatoes, Cucumbers, Peaches, Nectarines, or any other crop which is to root in the natural soil. For Melons, Ferns, Cyclamen, Chrysanthemums, Carnations, Bulbs, Zonal Pelargoniums, Heaths, Marguerites, Roses, and many other crops, soils have to be brought in and mixed in various proportions before use. The labour and expense of these operations are great, in addition to which large sums have to be spent on the erection of greenhouses and heating apparatus, the purchase of pots, &c.

§ 4. HOW SOILS HAVE BEEN MADE

It is from the sedimentary, organic, and igneous rocks that the farmer and gardener obtain the soil in which to grow their crops. When these rocks have been broken down into small particles and mixed in various proportions with organic material, they are capable of yielding up certain foods to plants with a proper supply of moisture and at a certain temperature.

The various rocks have been converted into soil by natural and artificial agencies. Amongst natural agencies the most important are the gases of the atmosphere, water (including rain, rivers, streams), wind, heat and cold (frost and snow), and vegetation. Amongst what may be called artificial agencies are the cultural operations of man—ploughing, digging, hoeing, harrowing, and manuring.

The natural agencies may be embraced in one word, "weathering", and the cultivator should impress upon his mind what important and powerful friends he has in them. The action of the weather—rain, frost, snow, sunshine, wind—never ceases; it is wearing away the face of the hardest rocks and flints, as well as the surfaces of cultivated soils, both day and night, and bringing them into a more fertile condition. This important work costs *nothing*, but how many realize that it is always going on!

It may be as well to consider the individual action of each of the natural agents.

Water.—Whenever rain falls it brings down a small quantity of

carbonic acid gas from the atmosphere with it. It falls on the earth and washes away fine particles from the hill and mountain sides into the plains and valleys. The mountain stream often becomes a torrent, and tears away great boulders, churning one against another, until they become rounded and worn away. The streams become rivers and eventually flow into the sea, and on their course they bring down masses of sand and silt, and deposit it in the lowlands. Many soils have been made in this way, and are said to be *alluvial*, because they have been washed on to a soil perhaps of a totally different nature.

Running water not only performs this work, but also gradually dis solves particles of rocks into a fine powder and wears away the face of them. This is called denudation. Water also fills the chinks and crevices in the rocks and carries out the same work slowly but surely. Being composed of the gases oxygen and hydrogen, and having a little carbonic acid in it, certain combinations with minerals and metals take place. What applies to rain and river water applies also to dew. If a piece of steel or iron is left in the open air for a night it soons turns rusty. This shows that the oxygen in the dew or rain has eaten into or combined with the steel or iron and produced rust. This eating away of metals by atmospheric gases is constantly going on, and in a few months a bright knife will be almost worn away by their action.

Rain is not merely a combination of the gases oxygen and hydrogen; it also contains small quantities of nitrogen and ammonia, chlorine, and sulphuric acid. From the Rothamsted experiments it has been proved that from 3·30 lb. to 4·84 lb. of nitrogen and ammonia is distributed over an acre of ground during the year; and it sometimes happens that a small annual rainfall will produce a larger supply of these gases. Chlorine equal to 25·3 lb. of common salt, and 17·41 sulphuric acid per acre, have also been found in the annual rainfall at Rothamsted.

Frost.—This is a powerful agent in producing a powdery soil. When water in the soil or in the crevices of hard rocks becomes frozen, it swells up and occupies more space. In cultivated soils the particles are easily pushed asunder, and are often raised up a good deal. In the case of rocks the force exerted by the swelling ice is so tremendous that it is irresistible. The rocks are therefore forced apart, splitting along the line of least resistance, and when a thaw sets in great pieces are broken off. Fresh surfaces are thus exposed to the weather, and the process of disintegration goes steadily on.

Heat.—This has the effect of warming the soil, and water in it, causing both to expand and one of them (water) to evaporate. As water is driven out of the soil in this way air enters, and thus makes the soil warmer than it was before. As the temperature of the air varies greatly between midday and midnight, sometimes as much as 60° F., one can readily imagine a kind of opening and closing—or expanding and contracting—movement going on continually on the crust of the earth, much in the same way that the tides rise and fall, although not so conspicuous. This variation of

temperature has its effect in splitting up the soil into smaller particles. Of course the temperature varies according to altitude, season, and climate, but it seems to be universal that night temperatures are always lower than day temperatures.

The temperature of the soil itself, as distinct from that of the air, varies according to the nature of the soil and the depth at which it is cultivated. All heat is derived from the sun, and the gardener seeks, in temperate climes at least, to secure as much as possible for his crops. Thus he likes to have his land with a gentle slope between the south-east and the south-west, because a larger surface is thus exposed to the direct rays of the sun. Even on level ground, if he is wise, he will always arrange his rows of fruit trees and bushes, Potatoes, Lettuces, Tomatoes, Peas, Beans, &c., running as near north and south as possible, so that the sun shall shine in between the rows at midday to warm the soil about the roots. If the rows run east and west, one will shade the other, with the result that the soil will have a lower temperature, the effect of which is less feeding activity of the roots.

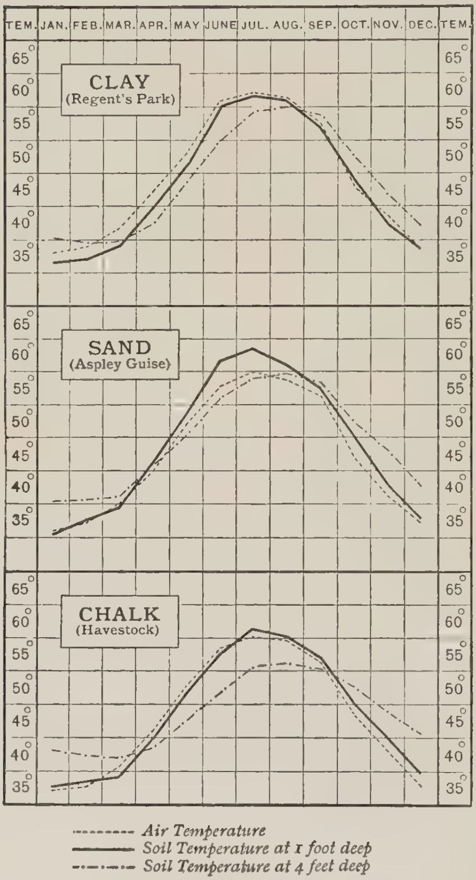


Fig. 84.—Variation of Temperature in Clayey, Sandy, and Chalky Soils

The annexed diagram, from *The Standard Cyclopædia of Modern Agriculture*, shows the variation of temperature in clayey, sandy, and chalky soils. It will be noticed in each case that the temperature of the soil at 4 ft. deep is always higher than that of the soil at 1 ft., and higher than the air, during the first three months of the year (January, February, March), and (in the case of clay and sand) during the last four months of the year (September, October, November, December). During the other months, April, May, June, July, August, the soil at 4 ft. deep is generally several degrees cooler than the air. The diagram shows the variations for the three soils.

Wind.—This plays an important part in the formation of soils. It sweeps over the surface, taking away the moisture from it, and in dry

SALPIGLOSSIS

(Three-fourths natural size)

weather the fine particles of dust and grit are borne from one place to another, together with leaves, twigs, and other organic material. Fresh surfaces are thus laid bare again for the action of rain, frost, snow, &c.

Vegetation.—It is thought that in the early stages of the earth's career only the lower forms of vegetable life could find a footing on its surface. The various Algæ, Lichens, Mosses, were able to pick up a living at first. In due course they died, and their remains mingled with the surface soil, thus gradually bringing about a compost suitable for the growth of higher plants—

> "Dissolve to dust and make a way
> For bolder foliage nursed by their decay".

And so on, from one stage to another, one class of plants succeeding another, and some even being crushed out of existence altogether, as we learn from the fossil remains found in coal seams, shale, &c.

Animals, when they came, helped also to make our soils, and, like the primitive plants, many of these died out under the stress of competition from newer races. Worms also play an important part in the ventilation of the soil, and wherever very large numbers are present it may be taken as a sign that the subsoil is in a wet and heavy condition, and should be trenched or at least double dug.

These natural soil-forming agencies, although of the greatest importance, are nevertheless too slow for horticultural and agricultural purposes. If a farmer or a gardener waited until the rain, frost, snow, heat, cold, and wind, &c., converted a heavy clay soil into a fertile condition, he and his race would soon become extinct. He therefore hastens the process of disintegrating various rocks and soils by such cultural operations as ploughing, digging, trenching, manuring, &c. He "tills" the ground, and by ever exposing fresh surfaces to the natural agencies of the weather, he, more or less quickly, brings the soil into a condition capable of bearing large crops of cereals, fruits, flowers, and vegetables. This condition is known as fertile, whereas a soil that will not respond to such operations is known as sterile.

§ 5. CULTURAL OPERATIONS

Ploughing.—Although regarded as being almost entirely an agricultural operation, many market gardeners also adopt this method of breaking up their open land, and often even use the plough between fruit trees and bushes when space permits.

Ploughing itself requires a good deal of skill on the part of the workman. A good ploughman will not only adjust the implement in such a way as to place as little strain as possible upon his horses, but he will also perform more good work in a given time than an unskilled or slovenly worker.

In ploughing, the surface soil only is broken up to a depth of 6 in. or 8 in., the width of each furrow being about 10 in. on an average. The cost of ploughing an acre of ground is about 15*s.*, but it may be more or

less according to the nature of the soil. From 1 to 1½ ac. can be ploughed in a day, and it is this facility for turning over the ground quickly that has made ploughing more popular than spade cultivation. When the ground is "subsoiled" a subsoil plough follows the other in the trench and moves the lower soil to a depth of 15 to 18 in. The cost of subsoiling 1 ac. of land would be about the same as for ploughing, thus making the total cost per acre for the two operations from 30*s.* to 40*s.* There are many kinds of ploughs now in use, but all have the same object in view, namely, to turn the soil up as well and as quickly as possible at the least expense.

One of the latest inventions is an electric plough, invented by Mr. E. O. Walker of Manchester. This is intended to supersede the steam plough, wherever electric power can be procured easily and cheaply. Electric wires overhead are used for a trolley as in tramcars, and the plough is hauled across the field from one side to another as in the case of steam ploughs. The same principles of shallow ploughing are adopted, but if

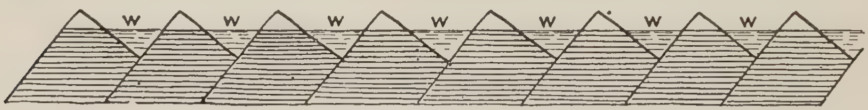


Fig. 85.—Diagram showing Water (W) standing between Ridges in Land ploughed 6 in. deep

electricity or steam could be harnessed in such a way as to turn the soil over to a depth of two or three feet, it would make a vast difference to the fertility of the soil in the course of a year or two.

The great disadvantage of ploughing is that the soil is not turned over to a great depth, and a hard pan is formed beneath the loosened layer. In some soils this pan is so hard that it is impossible for air or rain to enter the subsoil; and it is just as difficult, for the same reason, for the tender rootlets of the plant to extend their search for food. All the fertilizing advantages to be derived from the drying and warming action of the air, the solvent effects of the rain, and the penetrating power of the roots are thus rendered abortive, or at least greatly reduced. The diagram (fig. 85) shows how the water after a heavy rain remains on the surface between the ridges in ploughed land, until it is evaporated by the heat of the atmosphere and the wind. Under such circumstances the soil is cold and wet, and cannot be worked, while the beneficial bacteria cannot come into being in the soil until warmer and drier conditions prevail. The hard pan brought about by repeated ploughings has been recognized as such an evil by some American farmers, that they have taken the heroic measure of breaking the subsoil up by charges of dynamite.

Digging.—This operation is done with the spade or the fork. It is a much better way of turning up the soil than with the plough. Not only does the spade or fork go deeper, but the soil is turned over more completely, and the clods are broken down into much finer particles. An expert workman will dig from 8 to 15 rods (about 240 to 450 sq. yd.)

in a day, according to the nature of the soil. The cost of digging 1 ac. of ground 1 ft. deep will vary from 40*s.* to 55*s.*, more or less according to the state of the soil and the rate of wages in different parts of the Kingdom; and it will take one man from eleven to twenty days to perform the work properly, and turning over from 70 to 120 tons of soil each day.

Digging consists in opening a trench one spit deep, the full depth of the spade or the fork, and filling it with soil adjacent after lifting and turning completely upside down.

Double Digging.—Double digging consists in opening a trench twice as wide as in ordinary digging, and after the top spit has been removed, the bottom is then broken up but usually left in the same position. Manure is then added before the soil from the next top spit is placed on it.

Considering the depth of soil moved, the better breaking up of the particles, and the enhanced fertility, it is a question if digging is not on the whole a more economic method of cultivation than ploughing. One acre of dug ground will produce better and more saleable crops than 1½ ac. of ploughed ground of a similar nature. The extra cost of digging is therefore more than repaid by the increased yield and value; in addition to which must be reckoned the saving of half an acre's rent, the saving in gathering the crop over a smaller area, and the saving in subsequent cultivation. This proposition may appear more feasible if stated in figures. If an acre of ground dug by the spade or fork is only equivalent in yield to 1½ ac. of ploughed land, one may take the ratio on a larger scale, as follows:—

120 ac. ploughed = 80 ac. dug.

	£	*s.*	*d.*		£	*s.*	*d.*
Rent at £2 per acre =	240	0	0	Rent at £2 per acre =	160	0	0
Ploughing at 15*s.* per acre =	90	0	0	Digging at £2 per acre =	160	0	0
	330	0	0		320	0	0

It is evident that if a man can get as much produce off 80 ac. as he can off 120 ac., by a superior method of cultivation, he will be wise in adopting the superior method. He will employ far more labour, and he will be keeping men and their families on the land instead of keeping ploughs rusting in his barns. The question of labour and its arrangement of course requires careful consideration, so that the employees shall have work all the year round at a regular wage; but this is merely a matter of organization. The point for the commercial grower to consider is whether it will pay him better to spend say £330 per annum in half-cultivating 120 ac. of land, or whether it is more to his interest to spend £320—ten pounds less—in properly cultivating 80 ac. and reaping better results.

What is known as "bastard trenching" is taking out one spit of soil, and then taking up the loose soil or "crumb" at the bottom and spreading it over the top. Work like this will cost about 6*d.* per rod, i.e. £4 per acre.

Trenching.—This operation can only be carried out where there is a good depth of soil. Hence in hilly or mountainous districts, where only

a few inches of soil rest on hard rock beneath, trenching and even double digging is often out of the question.

When trenching ground, the soil is marked out in strips about 3 ft. wide, and the first trench is taken out to a similar depth. Before the soil adjacent is thrown into the trench in front it is a good plan to place a good layer of weeds, green vegetable refuse, twigs, &c.—in fact all coarse and untidy vegetation at hand—in the bottom. The only refuse to avoid putting in the trenches is Potato haulms and the clubbed roots of cabbage crops. These should be always burned to destroy the spores of the terrible diseases which often afflict them. Having prepared the first trench in the way indicated, the next piece of ground is marked off 3 ft. wide, and the soil from this, spit by spit and layer by layer, is placed in the trench, until this is of course filled up, and a new trench is along-

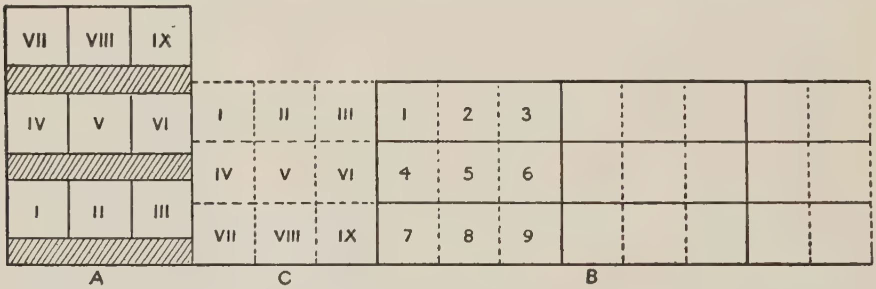


Fig. 86.—Diagram showing how ground may be trenched 3 ft. deep, bringing the bottom layer to the top to be fertilized by the weather, and to allow the free passage of air, rain, and roots downwards. Shaded portions indicate layers of manure. Note how trenched soil A is raised higher than the untrenched B. C shows how soil has been dug out and placed at A. In B the figures 1 to 9 show how the soil is to fill the trench C in the same way as at A.

side. Where plenty of refuse and manure are available it will pay to place a layer between the spits, keeping the best and most rotted manure for placing beneath the top spit. A kind of sandwich of soil and manure will thus be formed, as shown in the diagram (fig. 86).

Very few, if any, commercial gardeners adopt this system of cultivation, partly because of the cost of labour and manure, and partly because they fear that it would be one of the greatest mistakes possible to bring up the subsoil from a depth of 3 ft., and place it on the surface, especially if it happens to be of a clayey, sticky nature, or of gravel. But it would be well to remember the words of Virgil:

> "Well must the ground be digged and better dressed
> New soil to make, and meliorate the rest".

One can appreciate the argument against trenching on the score of expense; but if it is going to be done there will be no more, or very little more, expense or labour attached to bringing up the bottom spit and exposing it to all the fertilizing influences of the weather. As a rule this is the case. There is only one possible danger, and that is if the subsoil should contain a large proportion of ferrous oxide or protoxide

of iron. This is distinctly unfavourable to plant growth, and is often met with in yellow clay soil; but, as already stated at p. 97, it would be foolish to choose a soil of this nature in the first place. This poisonous ferrous oxide must not be confused with ferric oxide or peroxide of iron, which is a valuable constituent of the soil. It promotes vegetation and the development of the green colouring matter in leaves, and performs other useful functions.

Even if one is so unfortunate as to have a soil containing much poisonous ferrous oxide, the best way to remedy this defect is by bringing up the bottom soil and exposing it to the action of the weather. One of the most important changes that takes place is the absorption of oxygen from the air by the ferrous oxide, which in the course of time becomes converted into the useful and fertilizing ferric oxide.

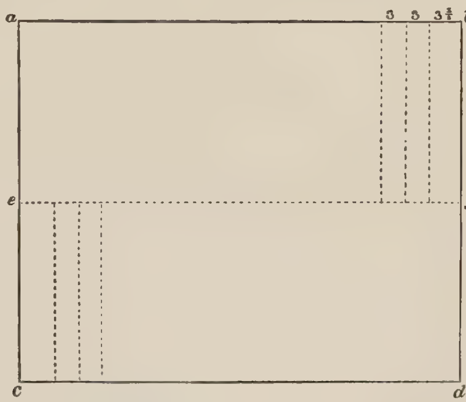


Fig. 87.—Diagram showing how the Ground may be marked out for Digging or Trenching

The cost of trenching soil to a depth of 3 ft. will vary from £8 to £12 per acre, an appalling item apparently to a man with limited capital; and then manuring, hoeing, &c., must be added, so that the cost of deep cultivation may well average £9 or £10 per annum per acre if vegetable crops only are to be grown. Against this great expense, however, must be placed the following advantages: (1) An abundance of available plant food; (2) earlier, heavier, and more remunerative crops; (3) abundance of warmth and moisture at the roots in the hottest of summers; (4) lack of insect pests and fungoid diseases; (5) saving in insecticides and fungicides; and (6) an absence of weedy vegetation and a consequent saving in plant food.

If it is intended to grow fruit trees and bushes, it would be even more wise to trench the soil to a good depth at first before planting, because once fruit trees are planted it will be afterwards almost impossible to rectify any troubles in the soil without incurring great expense. To bring soil into a proper condition for fruit culture, it may be advisable to crop it with Potatoes, Cabbage crops, Jerusalem Artichokes, Celery, Parsnips, &c., the roots of which would penetrate the soil deeply and break it into finer particles.

When digging, double digging, or trenching, it will be found convenient to divide the ground into convenient portions, as shown at *a, b, c, d* (fig. 87). By dividing each portion, as shown at *ef*, into two sections, a good deal of labour and wheeling will be saved. The soil from the first trench, *b* to *f*, when taken out, may be placed in front of the section *efcd* at *fd* When the work has reached *ae*, the trench there is to be filled with soil

taken from e to c. The work then proceeds to fd, and the soil which has been wheeled there from bf is used to fill the last trench.

Ridging Up.—This is an excellent cultural operation, and is almost equal in value to double digging. By digging a piece of ground lengthways, the soil from the trench is placed on the adjoining soil to the right or left, thus forming a ridge about 2 ft. high on one side and a trench correspondingly deep on the other. If the base of the ridge be 2 ft. wide, soil to cover one-half of it is taken from one side, and to cover the other half from the other side. In this way heavy soil is brought up, and a large surface is exposed to the weather. The soil in the bottom of the trenches on each side of the ridges may be still further improved by breaking up with the fork. A modification of ridging is to turn up a "spit" of soil and invert it in same place. The next spit is taken up and placed on top of the first, thus making a hillock and hollow alternately. Soil that has been ridged up in winter will be beautifully sweet and mellow in spring, when the crests of the ridges may be easily levelled down with a fork before sowing or planting operations.

Raking and Harrowing.—The rake is to the horticulturist what the harrow is to the agriculturist. They both have the same object in view—namely, to level the surface of the ground, and break the clods into powder so that it may be easier and better for the sowing of seeds. The rake is useful for small areas, but the harrow (of which there are several varieties) is adapted for drawing over large areas. The heavier harrows are useful in clearing off the weeds, as are also the chain harrows, while the lighter ones are used in connection with seed sowing.

Rolling.—This is also a horticultural and agricultural operation. Its object is to crush the clods still further, to make the surface more level, and to compress the particles sufficiently to hold moisture and make a firm root run. It would be fatal to growth to have large fissures in the soil, or to have it so loose and spongy that tiny seeds would sink down so deeply that the seedlings would never be able to reach the light. Rolling ground, or treading on it with the feet, therefore, has the effect of packing the soil particles together, without making them adhere so closely as to prevent the entrance of air and water.

Hoeing.—The hoe does not receive from the farmer or gardener the respect to which it is entitled. It is kept lying idle very often until the land becomes foul with weeds that have robbed the land of much of its food and moisture (see p. 116) that will cost more to replace than half a dozen hoeings.

The hoe should be in constant use while the crops are growing. It is invaluable as a food producer, a weed killer, and a moisture conserver, and when used with regularity the cost of hoeing an acre of ground, even by hand, is not great, perhaps 8*s.* to 10*s.* or 12*s.* at the most. When the soil has become overrun with coarse weeds, and the surface is also baked, the cost of hoeing an acre may be anything from 20*s.* to 30*s.*

The material advantages to be derived from regular hoeing are:

1. The upper crust is kept in a finely powdered condition. 2. Weeds are unable to grow and rob the soil of food and water, nor the air of carbonic acid gas. 3. By pulverizing the soil, fresh mineral foods are liberated for the roots by the action of the weather. 4. In hot seasons the freshly moved soil acts as a mulching and prevents the moisture escaping (see p. 123). 5. The dews are absorbed at night and are soaked down to the upper rootlets with fresh food. 6. The use of the hoe, especially during the summer months, prevents many insect pests from nesting in the soil, and the chrysalides of others are brought to the surface for the benefit of the birds. 7. As large supplies of food are liberated by the hoe, there should be a corresponding saving in the chemical manure bill, and as water is conserved, there is not only a better crop, but it also comes to maturity more quickly owing to the accelerated growth.

Taking these advantages into consideration it would pay every market gardener to keep his ground regularly hoed from February or March to October, and the money spent on it would be refunded over and over again.

§ 6. THE BEST TIME TO WORK THE SOIL

Whether the soil is to be ploughed, dug, or trenched in spring or autumn will depend largely upon its nature. Generally speaking it is better to turn up heavy soils in the autumn and light soils in the spring. As heavy soils contain a larger amount of dormant food than light soils, and as it takes longer to transform them into a soluble condition, it is better to have them ploughed, dug, or trenched during the autumn and winter months. Fresh surfaces are thus exposed to the action of the weather; clods are crumbled down into powdery masses by the action of frost, rain, snow, wind, &c.; the air enters more freely between the particles, and sourness and acidity are driven out by the sweetening action of the atmospheric oxygen. The soil thus becomes "sweeter"; it also becomes warmer, because better drained, and owing to the action of the carbonic acid in the air, and arising from decomposing manure, supplies of potash, phosphoric acid, nitrates, and other valuable foods become available by spring. At this period also the over-harsh clods are easily broken down by the rake or harrow, and can be rendered sufficiently fine for the reception of seeds of various crops.

If "light" land is ploughed, dug, or trenched in autumn precisely the same beneficial results would follow, but much more quickly. This would be a distinct disadvantage to the farmer and gardener at this season. Having no growing crops on the land to take up the freshly liberated food, there is a danger that this would be washed down into the lower layers out of reach of the roots. Thus, when sowing and planting time arrived in spring, although the soil would be easily worked, it is possible that the upper layer would be much poorer in plant food than it was before the autumn breaking up.

The cultivator therefore must always pay attention to the *physical* or *mechanical* condition of his soil rather than to its chemical composition, and he must regulate his operations accordingly. It may be stated as a good general rule, that whenever a crop is ready to be placed on the soil, it is a good plan to have it dug in advance whether it be spring, summer, or autumn.

§ 7. PLANT FOODS IN THE SOIL AND AIR

By means of experiment it has been proved that all green-leaved plants at least require certain essential foods to enable them to perform their functions properly. Some of these foods are absorbed from the air under the influence of sunlight, and some are taken from the soil by the roots. These essential foods are—

Carbon	Nitrogen	Potash	Iron
Oxygen	Phosphorus	Lime	Soda
Hydrogen	Sulphur	Magnesia	Chlorine

Silica.

These thirteen foods are found in all plants in varying proportions. The first four are gaseous and organic, and are driven from the plant by burning. The other nine are found in the ash of plants, and constitute the mineral or inorganic foods. When soluble in water, they are in a condition to be absorbed from the soil under favourable conditions.

Until about three hundred years ago it had been always thought that the soil supplied all the foods of plants and made up the great bulk of the tissues. Jean Baptiste van Helmont (b. 1577, d. 1644), a chemist of Brussels, was the first to disprove the old theory that all plant foods came from the soil alone. He planted a young Willow weighing 5 lb. in a pot containing 200 lb. of soil. He watered the plant daily with rainwater, and grew it for five years. He then weighed the plant and soil again and found that the Willow had increased from 5 lb. to 169 lb., but the 200 lb. of soil had lost only about 2 oz. Van Helmont therefore concluded that the extra 164 lb. weight of the Willow came from the water alone. In this he was wrong. He did not know that the invisible carbon in the air had anything to do with the increased weight of his Willow. Indeed it was not until a Dutch scientist, Jan van Ingenhuisz, published his researches in 1779 that it was discovered that the increase in weight was due to the carbon that had been assimilated from the atmosphere by the leaves during the daytime (see p. 44). It is evident, therefore, that only a very small proportion of plant food is actually taken from the soil itself. That little, however, is absolutely essential; and unless it is in a form easily dissolved in water, so that it may be absorbed by the roots, it is quite useless, and no growth can take place.

The figures on p. 109, compiled chiefly from Dr. A. B. Griffith's works,

FRUIT CROPS—ASH ANALYSES

Name of Crop.	Potash.	Phosphoric Acid.	Lime.	Sulphuric Acid.	Iron Oxide.	Magnesia.	Soda.	Chlorine.	Silica.
Apple, wood ...	19·24	4·90	63·60	0·93	1·66	7·46	0·45	0·45	1·31
Apple, fruit ...	56·21	10·89	4·87	3·05	1·93	6·53	14·02	0·68	2·82
Pear, wood ...	55·00	13·93	7·99	5·73	1·20	5·42	8·69	0·52	1·52
Plum, wood ...	56·99	12·09	6·39	3·33	5·21	9·25	5·24	0·20	1·30
Cherry, wood ...	21·63	7·56	30·24	2·62	2·62	8·72	1·84	0·81	24·96
Cherry, fruit ...	51·37	14·62	7·64	5·03	3·21	5·28	1·14	2·10	9·61
Peach, wood ...	52·61	13·69	4·88	3·21	1·20	4·10	11·89	0·55	7·71
Apricot, wood...	54·88	13·86	3·52	2·95	1·71	3·85	10·57	0·60	7·85
Apricot, fruit ...	60·20	12·00	4·26	3·06	1·26	2·12	9·68	0·45	6·91
Greengage, wood	58·09	13·99	9·81	3·62	5·00	6·28	0·12	0·61	2·48
Strawberry ...	41·40	11·70	12·21	3·15	11·14	2·93	1·29	2·78	12·05
Tomato, plant...	27·00	18·28	12·10	4·86	3·96	8·21	10·39	2·54	12·36
Tomato, fruit ...	53·04	14·53	4·38	...	0·92	3·97	...	...	...
Cucumber, plant	39·34	19·66	6·57	6·56	1·40	3·28	9·83	6·56	8·20
Cucumber, fruit	51·71	13·10	6·98	5·70	0·75	4·50	4·19	9·66	3·41
Grape vine ...	37·48	9·20	43·88	3·61	1·08	1·05	1·33	1·65	0·72
Gooseberry ...	38·65	19·68	12·20	5·89	4·56	5·85	9·92	...	2·58
Damson ...	45·98	13·83	12·65	2·37	1·19	8·17	5·66	...	9·22
Fig	28·36	1·30	18·91	6·75	1·46	9·21	26·27	...	5·93

VEGETABLE CROPS—ASH ANALYSES

Name of Crop.	Potash.	Phosphoric Acid.	Lime.	Sulphuric Acid.	Iron Oxide.	Magnesia.	Soda.	Chlorine.	Silica.
Cabbage ...	31·95	12·93	15·66	8·61	8·32	4·93	2·51	7·99	4·99
Cauliflower ...	34·39	25·84	3·07	11·16	3·67	2·38	14·79	2·78	1·92
Turnip ...	50·12	16·41	13·02	6·95	0·32	2·00	3·62	6·32	1·21
Kohl-rabi ...	48·69	16·75	13·65	6·82	0·48	3·18	3·89	5·31	1·23
Radish ...	23·65	40·12	8·92	6·97	2·10	3·64	3·01	3·59	8·00
Peas	20·10	40·10	6·90	2·00	1·40	8·90	17·30	1·20	2·10
Beans ...	42·50	34·66	6·00	3·50	0·40	7·30	3·34	1·40	0·90
Carrots ...	48·20	18·43	13·86	6·30	0·35	3·71	2·68	5·21	1·24
Parsnips ...	47·10	19·25	14·62	7·21	0·40	3·63	2·00	4·10	1·66
Celery ...	22·07	11·58	...	5·58	2·66	5·82	...	...	3·85
Beetroot ...	49·11	15·26	8·82	7·00	0·22	7·23	4·83	6·18	1·33
Lettuce ...	46·26	8·21	6·24	5·36	0·21	2·15	6·08	5·49	20·00
Endive ...	37·62	3·21	12·02	5·92	0·29	2·13	11·00	2·03	24·78
Rhubarb ...	30·00	18·13	14·21	5·04	3·68	7·33	9·78	2·03	8·06
Onion ...	32·35	15·09	13·66	8·34	12·29	2·70	8·04	4·49	3·04
Asparagus ...	6·01	18·51	4·39	4·13	3·31	3·03	34·21	12·94	13·47
Jerusalem Artichoke ...	44·62	14·97	8·36	5·21	4·31	6·89	9·63	2·98	13·03
Potato, tubers	55·75	12·57	2·07	10·62	0·52	5·28	1·86	7·10	4·23

will give some idea as to the various mineral foods taken out of the soil by different fruit and vegetable crops. These foods must be all soluble in water, and the temperature of the soil must be favourable, otherwise the roots would be unable to absorb them. It will be noticed that the same food is taken up by different crops in different proportions, and there is often a great difference in the composition of the wood and the fruit on the same plant. It should also be stated that the results obtained by different chemists vary greatly, probably owing to the plants tested being taken from different soils and at different times.

The quantity of these foods to an acre may be seen from the following analysis of Broadbalk Field, Rothamsted. The soil had not been manured for fifty years, and at 9 in. deep the weight of an acre was 2,500,000 lb. containing—

Carbon	22,250 lb.
Nitrogen	2,500 „
Soda	1,500 „
Potash	6,750 „
Magnesia	9,000 „
Lime	62,250 „
Alumina	112,250 „
Oxide of iron	85,000 „
Phosphoric acid	2,750 „
Sulphuric acid	1,250 „
Carbonic acid	32,500 „
Total ...	338,000 „

This particular soil lost about 4·20 per cent, or 105,000 lb., on ignition; 12·53 per cent, or 313,250 lb., was soluble in hydrochloric acid; and the undissolved siliceous matters were 83·27 per cent, or 2,081,750 lb.

These figures would indicate that there is an inexhaustible supply of food in the soil—far more than could be absorbed by many crops in the course of several years.

It has been estimated that an acre of fruit trees would require each year about 200 lb. lime, 150 lb. potash, 75 lb. nitrates, 50 lb. phosphoric acid. It would thus take over 311 years to exhaust all the lime in the Broadbalk Field at Rothamsted, 45 years to exhaust all the potash, 33 years to exhaust all the nitrogen, and 55 years to exhaust all the phosphoric acid. And it must be remembered that these quantities are given for an acre of ground unmanured for 50 years, and taken from only 9 in. deep.

In an American experiment, soil at 1 ft. deep (not 9 in.) gave 3,225,000 lb. weight to the acre, and was estimated to contain—

Phosphoric acid	6,772 lb. per acre.
Potash	32,897 „ „
Lime	47,407 „ „

An average of the results of forty-nine analyses of typical soils in America showed that the first 8 in. of surface soil contained—

Nitrogen	2,600 lb. per acre.
Phosphoric acid	4,800 „ „
Potash	13,400 „ „

In a good Hertfordshire soil analysed by Dr. Voelcker the following quantities of plant foods were found:—

Phosphoric acid ...	4,569 lb. per acre	(over 2 tons).
Potash	10,483 „ „	(„ 5 „).
Lime	74,188 „ „	(„ 33 „).
Magnesia	9,676 „ „	(„ 4 „).
Sulphuric acid ...	4,569 „ „	(„ 2 „).
Nitric acid	22 „ „	
Nitrogen	2,397 „ „	(„ 1 ton).

The surface soil from 9 to 12 in. deep is usually regarded as being more fertile than the subsoil beneath. Although farmers may accept this statement, many modern gardeners question it, for experience proves that by turning the soil over to a depth of 2, 3, and even 4 ft. magnificent crops can be secured. Indeed this has been proved for centuries by Chinese and Japanese gardeners, who are adepts at deep cultivation. Of course if the upper 9 or 12 in. of soil only are cultivated and manured it is possible to prove that it is richer in available plant food than the layers of soil immediately beneath. But actual practice proves that if the subsoil is also cultivated and manured, and brought up to be acted upon by the weather, it will gradually yield up the foods it contains.

The following comparison between the plant foods in the soil and subsoil is worth consideration:—

	Surface Soil.	Subsoil.
Silica, insoluble ..	59·26 per cent.	53·71 per cent.
Silica, soluble ...	2·63 „	3·96 „
Alumina	3·12 „	3·27 „
Iron	6·10 „	7·15 „
Lime	5·36 „	8·85 „
Magnesia... ...	0·02 „	0·21 „
Soda	0·93 „	1·02 „
Potash	1·53 „	1·89 „
Carbonic acid ...	7·00 „	10·36 „
Phosphoric acid ...	0·13 „	0·49 „
Sulphuric acid ...	0·63 „	0·94 „
Chlorine	1·20 „	1·32 „
Organic matter ...	12·09 „	6·83 „
	100·00 „	100·00 „

With the exception of organic matter (which can be easily supplied

by means of stable manure and other vegetable and animal refuse) these figures indicate that the subsoil really contains, on the whole, a larger supply of plant food than the upper crust. Owing to the fact that the latter is usually the only portion cropped it is not unnatural that it should lose some of its available food and thus become poorer. Thus one hears of a soil becoming "exhausted", by which is meant that it no longer yields the same quantity of good saleable produce as formerly, notwithstanding the fact that it has been cultivated and manured. The "top spit", which is therefore usually regarded as the best soil, may be really in a worse and poorer condition than the soil beneath it, owing to constant cropping, and because it is "always carefully kept on top".

If any reliance at all is to be placed on the figures quoted above from Dr. Voelcker and others, it is palpable that there is an enormous supply of plant food locked up in the earth, and if it can only be made available—not all at once, which would be fatal, but gradually—the cultivator has but to work his soil properly to liberate this food.

But this is just where the chemical theorist fails and where the cultivator comes in. Jethro Tull and the author of the Lois Weedon System of Cultivation were misled like many others with figures showing the abundance of food contained in their soils, but in practice they failed to obtain the best results. They practised deep cultivation, but they overlooked the fact that something besides a good supply of mineral food was also necessary. They overlooked the important factor of organic or stable manure and humus generally. It is as true now as in the days of Adam, notwithstanding our advance in the science of agricultural chemistry, that the gardener or the farmer who would reap the best results from his land must not only cultivate deeply, but he must also "load his fallow ground with fattening dung".

§ 8. HOW TO EXTRACT PLANT FOODS FROM THE SOIL

Assuming that the soil contains the food supplies already tabulated, the only way to bring them within the reach of any crop is by a rational system of supplying organic manures (see p. 145) and by deep cultivation. This is apparently a costly method, but it is really more economic than the prevailing system, as we shall endeavour to prove. In these days there is a good deal too much quackery about supplying foods to plants in a chemical and more or less unnatural form. Growers are told they have only to give their soil a dressing of this, that, or the other special manure, and their crops will be increased a hundredfold. There is never a suggestion of cultivating the soil deeply (that would sound too laborious), and the natural condition of the soil itself is rarely taken into account; whether it be clay, sand, loam, or gravel the same manures are recommended in all cases and under all circumstances. The result

in many cases is that the grower spends his money uselessly and thoughtlessly, and his crops are a failure instead of a success. Here and there, where the special manure happens *by accident* to suit the soil, good results are secured. The grower is delighted. He pins his faith to that particular brand, and uses it exclusively, until at length he finds that he has ruined his soil and lost his money. This system of cultivation is on a par with the methods of a man who seeks to keep himself in good health by the aid of somebody's much-advertised pills, without taking sufficient natural food or exercise. Sooner or later he becomes a physical wreck (like the soil), and the pills (like the chemical manures) no longer perform the miracles in his system they did when first used.

This view is borne out in a striking manner from the experiments on Wheat at Rothamsted, an account of which has been published by Mr. A. D. Hall in *The Book of the Rothamsted Experiments*, from which the following figures are taken:—

Table showing the Average Produce of Grain per Acre the First Eight Years (1844–51), and over the Successive Ten-year Periods

Plot.	Manures Applied.	Averages in Bushels of Grain over						
		8 Yrs., 1844–51.	10 Yrs., 1852–61.	10 Yrs., 1862–71.	10 Yrs., 1872–81.	10 Yrs., 1882–91.	10 Yrs., 1892–901.	50 Yrs., 1852–901.
2	Farmyard Manure	28	34·2	37·5	28·7	38·2	39·2	35·6
3	Unmanured	17·2	15·9	14·5	10·4	12·6	12·3	13·1
5	Minerals	—	18·4	15·5	12·1	13·8	14·8	14·9
6	Single Ammonium Salts and Minerals	—	27·2	25·7	19·1	24·5	23·1	23·9
7	Double Ammonium Salts and Minerals	—	34·7	35·9	26·9	35·0	31·8	32·9
8	Treble Ammonium Salts and Minerals	—	36·1	40·5	31·2	38·4	38·5	36·9
10	Double Ammonium Salts alone	25·1	23·2	25·1	17·3	19·4	18·4	20·7
11	Double Ammonium Salts and Superphosphate ...	—	28·4	27·9	21·7	22·7	19·5	24·0
12	Double Ammonium Salts and Sulphate of Soda ...	—	33·4	34·3	25·1	30·1	26·7	29·9
13	Double Ammonium Salts and Sulphate of Potash ...	—	32·9	34·8	26·8	32·5	29·6	31·3
14	Double Ammonium Salts and Sulphate of Magnesia	—	33·5	34·4	26·4	31·1	25·0	30·1

From these figures it will be seen that, while the yield per acre from farmyard manure steadily increased, except in one decade (1872–81), from 28 bus. of grain per acre to 39·2 bus., in every case of chemical manures except the "treble ammonium salts and minerals" there was a conspicuous and remarkable decline in the yield. All plots show a big drop for the decade 1872–81, "a period of notoriously bad seasons", as Mr. Hall states. A recovery then took place, but it was as marked in the "unmanured" plot, No. 3, as in some of the others. Indeed the unmanured plot recovered more effectually than did Plots 5, 10, and 11. Comparing the average yields over the period specified, it will be noticed that while farmyard manure shows an increase from 28 bus. in 1844 to 39 bus. in 1901, all the

others show a decrease, with the exception of the plot that had been manured by "treble ammonium salts and minerals". The drop in yield is so remarkable that it is worth while to state it in tabular form, thus:—

	Plot 2.	Plot 3.	Plot 5.	Plot 6.	Plot 7.	Plot 8.	Plot 10.	Plot 11.	Plot 12.	Plot 13.	Plot 14.
	bus.	bus.	bus.	bus.	bus.	bus.	bus.	bus.	bus.	bus.	bus.
1st Year ...	28·0	17·2	18·4	27·2	34·7	36·1	25·1	28·4	33·4	32·9	33·5
50th Year ...	39·2	12·3	14·8	23·1	31·8	38·5	18·4	19·5	26·7	29·6	25·0
+ Increase or − Decrease	+11·2	−4·9	−3·6	−4·1	−2·9	+2·4	−6·7	−8·9	−6·7	−3·3	−8·5

In Plots 2, 3, and 10 the experiments commenced in 1844; all the others commenced in 1852. Plot 2 received farmyard manure, and shows an increased yield of 11·2 bus. per acre. Plot 3 was "unmanured", and at the end of fifty-eight years shows a decline of 4·9 bus. per acre. It will be noticed, however, that this decline is greatly exceeded in the chemically manured Plots 10, 11, 12, and 14, which show a drop of 6·7, 8·9, 6·7, and 8·5 bus. respectively; while Plot 6, which received single ammonium salts and minerals, only beat the "unmanured" plot by the skin of its teeth—4·1 against 4·9. Out of eleven plots, therefore, it appears that four plots (Nos. 10, 11, 12, and 14) had a much larger decrease in yield than the "unmanured" plot; while four others (Nos. 5, 6, 7, and 13) were almost as bad as the plot that had received no manure at all.

Taking the highest yield—that produced by the application of farmyard manure and the treble ammonium salts and minerals—the yields of 39·2 bus. and 38·5 bus. are by no means remarkable. They are both under 5 qr. to the acre, so that at £2 per quarter the return is only about £10 per acre for the grain. To this must be added the sale of the straw, averaging from 34 to 40 cwt. per acre, making the gross return about £12 to £14 per acre. From this must be deducted the cost of labour and manures, rent, rates, and taxes, so that farming and manuring on the Rothamsted principle would appear to be a very precarious business. The cultivation seems to be of the poorest description; in fact it can hardly be described as cultivation at all. "The usual practice", says Mr. A. D. Hall in his account of the experiments, "is to scuffle the land immediately after harvest, and remove the weeds; the land is then ploughed 5 or 6 in. deep; the mineral and other autumn-sown manures are sown and harrowed in, after which the seed is drilled." One can imagine the condition of the soil 6 in. from the surface after fifty years of such "cultivation". It must be almost as hard as rock, and impervious to rain, air, or roots.

To obtain some idea as to what Wheat really could do if cultivated on horticultural instead of agricultural lines, the writer carried out the following experiment at Ealing in 1910: Ordinary English Red and White Wheat obtained from a flour mill—200 seeds of each—were sown at a foot apart each way on March 14. They germinated on April 9, and caused some amusement owing to their scanty herbage and lonely appearance. By

August the plants had tillered and grown fairly well, but were not considered satisfactory, although they averaged 2½ to 3½ ft. in height. On September 24, the plants being sufficiently ripe were cut, and the following results were tabulated: Out of the 400 plants, about 40 failed altogether, that is 10 per cent. The best plant had 83 stems, and bore 45 ears of corn, the gross weight of the plant being 2 lb. Other plants had 50 stems and 37 ears; 39 stems and 36 ears; 37 stems and 17 ears; and the very poorest had 24 stems and 11 ears, and a weight of 1 lb. The average per plant for the whole crop was 46·6 stems, 29·2 ears, and 1·45 lb. Taking an acre of wheat grown on these lines, there would be about 40,000 plants, producing an aggregate of about 2,000,000 stems and 1,200,000 ears of corn, having a gross weight of nearly 26 tons, of which 19 tons may be regarded as straw, and 7 tons as corn; or over 31 qr. of wheat per acre. By tilling the ground deeply and well on true horticultural principles, there is no doubt but that far larger supplies of wheat—two, three, and four times as much—could be obtained from the acreage already under that crop. The cost of producing it would be increased naturally, but taking an average of four years' cultivation and manuring, it need not exceed an average of £9 10*s.* per acre per annum, apart from cutting. The cost of cultivating wheat on horticultural lines, as indicated above, and the receipts, may be estimated as follows:—

EXPENSES PER ACRE	£	s.	d.	RECEIPTS PER ACRE	£	s.	d.
1st year, Trenching 3 ft. deep ...	12	0	0	160 bus. Grain = 20 qr. at £2 =	40	0	0
				12 tons Straw at £2 =	24	0	0
2nd ,, Digging 1 ft. deep ...	2	0	0	176 bus. Grain = 22 qr. at £2 =	44	0	0
				13 tons Straw at £2 =	26	0	0
3rd ,, ,, ,, ,, ...	2	0	0	192 bus. Grain = 24 qr. at £2 =	48	0	0
				14 tons Straw at £2 =	28	0	0
4th ,, Double Digging 2 ft. ...	5	0	0	240 bus. Grain = 30 qr. at £2 =	60	0	0
				16 tons Straw at £2 =	32	0	0
Hoeing twice each year at 25*s.*	5	0	0				
12 tons Manure each year at 5*s.* per ton = £3	12	0	0				
	38	0	0				
Balance 4th year ...	264	0	0				
	302	0	0		302	0	0

To the average agricultural mind these figures may appear extraordinary. If, however, it is possible to obtain 5 qr. of wheat year after year merely by scuffling over the ground to a depth of 6 in., there is nothing very remarkable in obtaining four and five times as great returns from soil that has been deeply tilled, well manured, and thinly sown. After all an average turn over of £75 10*s.* per acre is much better than £12 or £14, although the cost of cultivation is greater on horticultural principles than it is on agricultural ones. Once the land has been broken up, if the spade and the fork and the hoe are substituted for the plough, not only would wheat growing be revolutionized, but thousands of men would be kept on

the land at better wages, and our wheat crops would be increased enormously. Agriculturists would do well to consider the above figures before smiling too broadly at them.

The annexed diagram (fig. 88) will show at a glance the great advantages to be secured by deep tillage. At A, where the soil is dug out 1 ft. deep, the roots are restricted; at B, showing soil dug 2 ft. deep, a larger mass of roots develop and absorb more food; while at C, dug 3 ft. deep, a still larger mass of roots search the soil for food, and no matter how dry

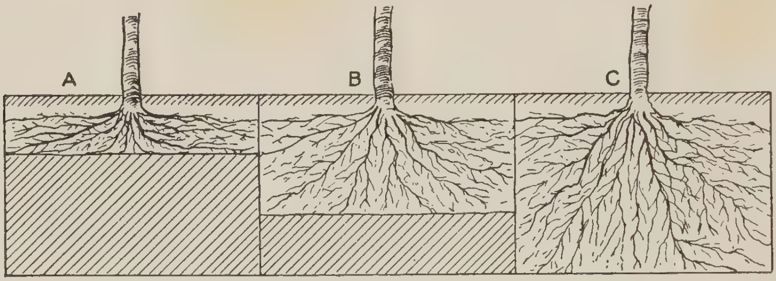


Fig. 88.—Diagram showing the Root Development in Soil dug 1 ft. deep (A), 2 ft. deep (B), and 3 ft. deep (C). The shaded portion shows the hard, impervious, and unbroken subsoil

the summer may be the tender feeding tips are always in the midst of plenty of food and moisture.

§ 9. WATER IN THE SOIL

Water, being essential for all plant growth, must be present in sufficient quantity in the soil, and in such a condition that it can be absorbed by the roots. Water may be in such abundance in some soils that its presence would be more harmful than useful to the crop. Thus in a clayey soil that has been only broken up with the spade or the plough from 6 in. to 12 in. deep there may be so much water present that the soil becomes chilled and waterlogged, and plants fail to grow because the soil bacteria remain inactive (see p. 125).

The quantity of water in a soil depends upon the rainfall. This varies in different parts of the United Kingdom from 24 or 25 in. in the neighbourhood of London, and along the eastern counties of England and Scotland, to 40 in. in the south-western districts; while in the western Highlands, the Lake District, and parts of Wales the annual rainfall is about 80 in. An inch of rain to the acre represents something over 100 tons of water to the acre; so that in the British Islands the amount of water which falls upon an acre of soil varies from 2400 tons to 8000 tons annually. It penetrates the soil more or less readily according to the nature of the soil itself, and the way in which it has been cultivated. Thus on a clayey, uncultivated soil very little rain will

pass straight downwards. It will flow away from the surface to the ditches, or remain in pools in the shallow places—just as it does on roadways and pavements. On a sandy soil, the rain will pass down and between the particles readily until it comes to the water-table beneath; and in loamy or peaty soils a good deal of water will be absorbed.

Different soils will absorb and retain water in different proportions, as shown by the following experiment of Schübler:—

Table showing Absorption and Evaporation of Water in Various Soils

	Water Absorbed by 100 Parts of Soil.	Evaporation in 4 hr. from 100 lb. of Water at 66° F.
	per cent.	lb.
Sand	25	88
Clay, loamy	40	52
Clay, heavy	61	35
Clay, pure...	70	31
Rich garden soil	96	25
Peat mould	190	21

This is a laboratory experiment, and cannot therefore be regarded as giving the same results as one would find in the open field, and in actual practice. So much depends upon the way the soil has been treated. Where the soil has been deeply dug or trenched far more water will be absorbed than where it has been allowed to become hard and baked on the surface. It therefore pays to cultivate the soil deeply and well if full advantage is to be taken of the rainfall, and if the soil is to store up sufficient moisture for the roots of the crops during hot and rainless summers.

The above table teaches the market gardener that a soil which has been well dressed with organic material like stable manure, peat-moss litter, &c., will absorb and retain moisture for a very long period—but only in accordance as to whether it has been cultivated to a great or little depth. That is the important point for practical growers to bear in mind. Unless the soil has been well opened up by digging, trenching, or subsoil ploughing, it will lose its moisture very rapidly, and crops will suffer intensely in consequence during a hot dry season.

How Moisture is Lost.—Soils lose moisture in four ways: (1) by natural evaporation from the surface; (2) by bad and shallow cultivation; (3) by transpiration from the leaves of the crops grown; and (4) by the leaves of weeds allowed to grow.

The loss by natural evaporation will depend upon the temperature of the atmosphere and the dryness or otherwise of the season. The higher the temperature and the drier the atmosphere the greater the evaporation from the surface. This is so well known to gardeners who grow produce under glass that special care is taken to counteract the heat and

dryness by saturating both soil and atmosphere with moisture with the hose or water pot. The only market gardeners who do the same thing in the open air in a systematic manner are the intensive cultivators or *maraîchers* in France and Holland. British fruit-growers and market gardeners, owing to the large areas they crop, find it physically impossible to apply sufficient moisture to their crops; hence they suffer great losses in dry seasons.

The diagram (fig. 89) will give an idea as to how water either rests on the surface of the soil if hard and caked, or how it sinks down to a depth of 1, 2, 3, or more feet if the soil has been broken up to such a depth. It is obvious from the diagram, in which the soil has become hard and baked, or is of a clayey nature and uncultivated, that most of the rain that falls remains on the surface, and will be soon evaporated. In the diagram, where a similar soil has been cultivated and turned up more or less deeply, more water will sink into the soil, and it may be taken that the powers of absorption will be as stated on p. 120, according

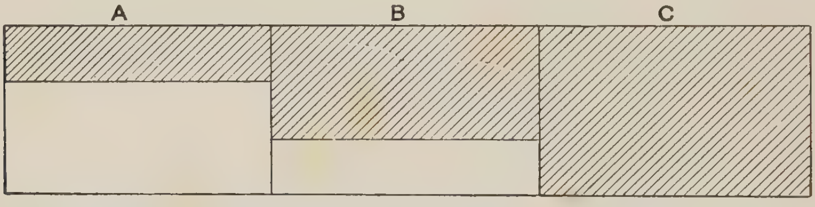


Fig. 89.—Diagram showing Soil dug 1 ft. (A), 2 ft. (B), and 3 ft. (C) deep at the shaded portions. The unshaded portions show the hard, impervious, and unbroken subsoil

to the nature of the soil. The deeper, therefore, a soil is cultivated, the more moisture it will hold for the benefit of the crops.

Loss of Water through the Leaves.—In addition to the water lost by natural evaporation and by shallow cultivation, a vast loss is sustained owing to the moisture that is given off from the leaves of the crops. Stephen Hales (b. 1677, d. 1761) was the first to discover that leaves gave off moisture, and an account will be found in his *Vegetable Staticks, or Experiments on the Sap of Vegetables*, published in 1727. The quantity of water taken out of the soil by various crops is stated by H. W. Wiley, in his *Agricultural Analysis*, to be as follows per acre:—

Crop.	Lb.		Tons.	Equal to Inches of Rain per Acre.
Wheat	409,832	=	183 nearly	1·83
Clover	1,096,234	=	489	4·89
Sunflower	12,585,994	=	5619 nearly	56·19
Cabbage	5,049,194	=	2254	22·54
Grape vines	730,733	=	326	3·26
Hops	4,445,021	=	1984	19·84

The accuracy of these figures may be doubted. If an acre of Sun-

flowers, for instance, required 5619 tons of water (equivalent to 56 in. of rain) to mature, it is obvious that they could not be grown in many parts of eastern Great Britain, where the total annual rainfall only averages 24 or 25 in., or 2400 to 2500 tons per annum. As the Sunflower crop would require only about 150 days at the most to mature, from start to finish, something like 38 tons of water (or ·38 in. of rain) would have to fall on an acre of ground each day. Assuming that 10,000 Sunflowers were grown to the acre, this would mean that each plant would absorb and transpire about 8½ lb. of water per day.

Professor Bentley, in his *Manual of Botany*, states that "a common Sunflower, 3½ ft. high and weighing 3 lb., gives off on an average 20 oz. of water; and a Cabbage plant about 19 oz. of fluid in a single day".

It may be remarked that a Sunflower 3½ ft. high and weighing 3 lb. is a poor specimen. Taking an average specimen, 6 ft. high and about 6 lb. in weight, it bears about 30 leaves, each with a superficial area of about 45 sq. in. The total transpiration leaf surface for one Sunflower is therefore about 1350 sq. in. Assuming that a plant of this size will transpire only 24 oz. of water per day for 150 days, each plant will transpire in the season 225 lb. of water from its leaves, or over 1000 tons for a crop of 10,000 plants to the acre. Assuming also that each plant, when fully grown, contains 4 lb. of water, that would give 40,000 lb., or about 18 tons, more moisture taken from the soil. It would therefore appear that an acre of Sunflowers would require about 1020 tons of water (equal to 10 in. of rain) in the course of the year.

The figures on p. 120 give an idea as to the approximate quantity of water taken out of the soil during the growing season by various crops.

It will thus be seen that such crops as Sunflowers, Jerusalem Artichokes, and Cabbage crops require at least 10 in. of rain in 150 days to enable them to flourish, while Beetroot and Lettuces require over 23 in. of rain, and Runner Beans require about 26 in. in the course of about 100 days. If all the rain that falls is not absorbed by the soil, it is evident that the crops must suffer, unless moisture can be kept round the roots in some way.

Mr. A. D. Hall, in his book on *The Soil*, calculates that 300 lb. of water transpired is equivalent to 1 lb. of dry matter. It is obvious that the amount of water given off will depend largely upon the season, whether wet or dry, hot or cold, and also upon the way the crops are cultivated, and whether they are planted at proper distances apart, and are in a free-growing healthy condition, free from insect pests and fungoid diseases. The nature of the crop itself must also be taken into account. Some plants containing very little dry material (e.g. Lettuces, Turnips) would give off more moisture than others of a more woody nature. And again, some very fleshy plants, like most of the Cactaceæ, many of the Euphorbiaceæ, and of the Asclepideæ (like Stapelias, Haworthias), and such plants as Stonecrops, are specially adapted to conserve their moisture even in the hottest weather, owing to the very few stomata on their

TABLE GIVING AN ESTIMATE OF THE AMOUNT OF WATER TRANSPIRED FROM THE LEAVES OF VARIOUS CROPS DURING THE GROWING PERIOD

Crop.	Number of Plants to One Acre.	Water given off per Plant per Day.	Total Water given off by Crop per Day per Acre.	Period of Growth in Days.	Water evaporated by Crop during Period of Growth per Acre.	Approximate Amount of Water in Crop when Mature per Acre.	Total Water taken out of Soil by Evaporation, and Weight per Acre.	Equivalent to Rain in Inches.
		oz.	lb.		tons.			
1. Sunflower... ...	10,000	24	15,000	150	1000	at 4 lb. = 40,000 lb.	1000 + 18 = 1018	10
2. Jerusalem Artichoke	10,000	24	15,000	150	1000	,, 4 ,, = 40,000 ,,	1000 + 18 = 1018	10
3. Beetroot	70,000	8	35,000	150	2344	,, 1 ,, = 70,000 ,,	2344 + 31 = 2375	23
4. Cabbage (summer)	10,000	24	15,000	150	1000	,, 4 ,, = 40,000 ,,	1000 + 18 = 1018	10
5. Lettuce	40,000	16	40,000	130	2321	,, 3 ,, = 120,000 ,,	2321 + 54 = 2375	23
6. Rhubarb	5,000	48	15,000	180	1205	,, 5 ,, = 25,000 ,,	1205 + 11 = 1216	12
7. Dwarf Beans ...	40,000	16	40,000	100	1785	,, ½ ,, = 20,000 ,,	1785 + 9 = 1794	17
8. Runner Beans ...	30,000	32	60,000	100	2678	,, 1 ,, = 30,000 ,,	2678 + 13 = 2691	26
9. Potatoes	5,000	48	15,000	120	888	,, 5 ,, = 25,000 ,,	888 + 11 = 899	8
10. Turnips	60,000	16	60,000	100	2678	,, ½ ,, = 30,000 ,,	2678 + 13 = 2691	26
11. Apples	320	1400	28,000	150	1875	—	1875	19
12. Pears	320	1800	36,000	150	2400	—	2400	24
13. Plums	320	2000	40,000	150	2678	—	2678	27

surfaces. Many of these are protected from the glaring sun by hairs, spines, bristles, or by a waxy "bloom", consequently the amount of moisture given off from their surfaces is very small.

Movement of Water in the Soil.—We have already seen (p. 118) that the deeper a soil is cultivated the more water it will absorb, no matter what its character may be. This water sinks down and down until it comes to a level where water is always standing. This water level or water table may be from 3 to 150 ft. beneath the surface, and may be taken to represent the reserve supply locked up in the soil. It is obvious that all the rain that falls does not reach the water table, because it is waylaid *en route* and absorbed by the particles of soil. And it must be remembered that although more rain falls in the hilly districts, the soil on the hillsides is not moistened so deeply as that in the lowlands and valleys. In the latter places, apart from the natural annual rainfall, a good deal of extra water is obtained when the rivers and streams overflow their banks at floodtime. When the fields and meadows are flooded to a depth of 1, 2, or 3 ft., many hundreds of tons of water are thus spread over the land, and a very large quantity of it must sink downwards to the water table if the soil is in a porous condition.

Water Lost by Weeds.—Many growers do not appreciate the quantity of water that is stolen from the soil by weeds. After all, weeds are plants —outcasts of the horticultural world, but they must live, if allowed to remain on the ground. Being more vigorous in their nature than cultivated plants, they need large supplies of moisture to keep them going, and they transpire through their leaves at least as freely as do cultivated crops. It therefore follows that if an acre of ground, carrying, say, 40,000 Lettuces or 10,000 Cabbages, is allowed also to carry a crop of weeds between, the amount of water taken up from the soil and evaporated in the course of the season will be probably twice as great as if no weeds were allowed to grow. The commercial gardener should therefore decide whether it is cheaper and better for him to allow weeds to grow and steal the moisture and food from his Cabbages, Carrots, Beets, Lettuces, and fruit trees or bushes, or whether it is more remunerative to spend money in keeping the weeds down, and thus conserve the moisture and food for his crops. The sensible grower will, of course, spend money in labour for hoeing by hand or machine between his crops, because he knows he will not only keep his crops clean, healthy, and steadily growing with the moisture he is conserving, but also because he knows that freshening up the surface of the soil means more food for the roots of his plants, fewer insect pests in the soil, greater absorption of rain and dew, and consequently crops that are likely to sell more quickly and fetch higher prices than those that have been neglected.

During the summer months it is not at all uncommon to see the ground between rows of fruit trees and bushes, and between vegetable crops, full of weeds. These are not only robbing the air of carbonic acid gas (see p 108). but also the ground of moisture, and leaving it in a parched and

cracked condition. The weeds also harbour the grubs of various fruit and vegetable pests that sleep in security until nature calls them forth again to plague the grower who despises knowing anything about them. The prevalence of weeds, therefore, in any garden indicates a penny-wise saving in labour and a pound-foolish extravagance in other directions.

The Upward Movement of Moisture in Soils—Capillary Attraction.—We have seen that according to the nature of the soil, and the depth to which it has been cultivated, large or small quantities of water are absorbed and sink to certain depths. If, however, the water were to sink so low as to leave no moisture at all in the root region, plant growth would be impossible. We know, however, that in all well-cultivated soils there is generally a good supply of moisture available, even in the hottest and driest of summers. Whence does it come? Obviously from the supplies deep down below the surface.

The soil may be looked upon as a kind of sponge. It will not only soak in water from overhead, but also from beneath. Consequently we find that when no rain falls, and the weather is hot and dry, a good deal of moisture is rising from the ground. This is easily proved by placing a piece of glass on the surface of the soil. After a short time it will be noticed that the under surface is covered with moisture that could not escape through the glass. If we dig down for 2, 3, or several feet we see no actual water, but we notice that the soil becomes more moist the deeper we go, until eventually we should reach water. It is evident, therefore, that the moisture rises upwards, and passes from particle to particle of the soil. A kind of invisible stream of vapour is constantly rising from the lower regions, and is given off from the surface of the soil into the atmosphere. This upward stream of moisture or vapour is caused chiefly by the evaporation that is going on from the surface owing to the heat of the sun. The top layer of soil particles are the first to lose their moisture, then the next layer, and so on downwards, until, if no rain falls, and the reserve of water beneath fails, the soil becomes as "dry as dust", and the crops collapse.

The ascent of water or moisture in the soil is much the same as it would be in a sponge or in a slab of salt or sugar. The lowest layers in direct contact with the liquid are more saturated than those above them, and the particles composing the different layers have the power of drawing moisture from those immediately below them. According to the nature of the soil this power of raising the water from below upwards varies greatly. Thus, in a heavy clay soil, where the particles are closely pressed together, it is very difficult for the moisture to rise freely. The surface layers lose their moisture after a time, and then, because they are unable to obtain a supply from those beneath, the surface begins to shrink and crack and form fissures in all directions.

In a sandy soil, where the particles, although closely packed, are not cemented together as in clay, moisture is given off very freely, and the

upper crust very soon becomes dry and hot, and almost incapable of supporting any plant life.

In a loamy soil, however, which is a mixture of sand, clay, and organic material, moisture arises neither too quickly nor too slowly. It is, therefore, retained round the roots for a longer period.

The ascent of moisture depends not only upon the nature of the soil, but also upon the way in which it has been cultivated. We find even in good garden soils that have been dug only 9 in. or 1 ft. deep, that the moisture soon vanishes from this upper layer. The subsoil beneath is probably too firmly compressed to allow the moisture to travel upwards freely. The same thing is seen in soils that have been ploughed year after year. The upper layer of 6 in. or 9 in. rests upon a very hard "pan", through which water can neither penetrate downwards nor rise upwards.

If, however, we take a soil that has been broken up to a good depth, say 2 and 3 ft., it will be noticed, even in the hottest and driest summers, that there is always sufficient moisture available for the roots of the plants growing on it, and they appear to be as fresh and green as if they were supplied overhead with abundance of water each day.

The way in which the water passes upwards from layer to layer and particle to particle of the soil is known as capillary attraction. The direction of the liquid is always from the wet to the dry, and the finer the particles of soil, and consequently the narrower the interstices between them, the greater the height to which the moisture will rise.

This may be demonstrated by taking some glass tubes with bores of various diameters. If placed on the surface of water it will be noticed that the liquid will rise higher and more quickly in the tube with the smallest bore.

It is possible also that the pressure of the atmosphere has something to do with this ascent of liquid in the soil. The air spaces between the particles may be regarded as so many fine-bored tubes, up which the water passes. Owing, however, to the heat at the surface, the air and the moisture become warmer and lighter, and rise upwards. A kind of vacuum is thus caused, or at any rate both air and moisture are less dense than at a lower depth. The equilibrium between top and bottom is thus upset, and the water and air from beneath rush upward, owing to the pressure of the atmosphere, to fill the vacuum caused, and to restore the balance. During a hot day this process is going on vigorously, and moisture rises to the surface in the same way that oil is drawn up the wick of a lamp by the heat of the flame at the top.

Every gardener who sows the spores of Ferns, or such fine seeds as those of Gloxinias, Begonias, Rhododendrons, &c., takes advantage of the capillarity of the soil, by dipping the seed pots in water, and allowing the moisture to rise upwards to the surface instead of watering overhead.

Conserving the Moisture in Soil—The Use of Hoeing and Mulching.—While the aim of the open-air cultivator should be to prepare his soil

for the reception of plenty of moisture and its ascent afterwards to the roots of his crops, he must also take care that the supply of moisture does not become exhausted during hot and rainless seasons. The experiment of putting a piece of glass on the surface of the soil to collect the moisture arising from it indicates a way in which moisture may be prevented from escaping into the air from the soil. A piece of board or slate would act in the same way as the glass, although the moisture would not be so apparent. Indeed, layers of almost anything put on the surface of the ground will check the moisture escaping from it freely. The cultivator naturally wishes to keep the moisture in the soil, because it is the only means by which the foods from the soil can be transmitted by root action to all parts of the plant, and because it saves him the labour of watering. Sheets of glass, slates, boards, &c., however, are not the most suitable materials for keeping the moisture in the soil. The grower has found that by placing a layer or mulching of more or less decaying manure on the surface of the soil he not only prevents moisture escaping freely, but he also prevents weeds from growing and robbing him of food and moisture. In addition to this, as the manure gradually decays it yields up to the soil certain valuable foods that are sooner or later washed down to the roots by the rains. The manurial layer also prevents the sun from scorching and baking the soil, and, being a bad conductor of heat, this is a consideration in hot seasons. Layers of short grass, leaves, leaf mould, moss, &c., would act in the same way as the manure.

When these materials are not available, it is still possible to conserve the moisture by stirring up the surface of the soil to a depth of two or three inches by means of the hoe or scarifier. At first sight it would seem as if breaking up the surface soil would facilitate and accelerate the escape of moisture from the soil beneath. Such, however, is not the case. When the surface is broken up with the hoe a layer of loose soil is then placed over the more consolidated soil beneath. In the latter the moisture is rising freely; but when it comes in contact with the loose layer the particles of soil in it are no longer so closely bound together that the moisture can pass readily to them. Consequently a check to evaporation from the surface takes place, and the moisture is kept in the soil for a longer period. The loosening of the surface soil indeed produces a kind of soil blanket which checks the rapid absorption of heat from the air, and the rapid evaporation of moisture from the soil at the same time. The roots of the crops are therefore kept in a cool, moist, and highly active condition during the hottest seasons.

In some experiments carried out in America by Professor King on a sandy loam, it was proved that in a hundred days the unmulched soil lost water equal to 6·55 in. of rain, or 655 tons to the acre. When mulched 1 in. deep, the soil only lost water equal to 3·30 in., or 330 tons per acre; at 2 in. deep about 299 tons per acre; at 3 in. 254 tons per acre; and at 4 in. 278 tons per acre. It would thus appear that a mulching or loosening of a soil to a depth of 3 in. gives better results.

It should not be forgotten that, apart from the benefits of retaining moisture in the soil during a hot summer by loosening the ground with the hoe, other advantages are also secured. The loose and more finely powdered soil absorbs the dews more readily, inorganic foods are liberated, and the grubs or pupæ of various insect pests are brought to the surface where they are readily pounced upon by the birds.

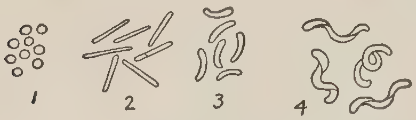
§ 10. LIVING ORGANISMS IN THE SOIL

It has already been shown (p. 108) that mineral foods alone are insufficient to supply all that is needed for plant life. Scientific investigation has proved that the soil, if properly cultivated, is teeming with life. Millions of minute organisms or bacteria are working away in the dark converting the minerals and metals of the earth into plant food, with the aid of the fresh air and the organic manures. This explains why tons of stable or farmyard manure and vegetable refuse of all kinds vanish after a time in the soil. It has been eaten away by the bacteria, and in the process a certain amount of heat and fermentation have been generated. This heat (more or less according to the condition of the manure applied), in conjunction with a proper amount of moisture and fresh air, dissolves some of the mineral substances, and brings them into such a condition that they are readily absorbed by the roots. So long as all the necessary factors are present the work goes on steadily; but if one or the other is absent or in a poor state the whole work is impeded. If lime, or manure, or both be absent no bacteria come into existence and no changes take place. Hence a soil without them would be as sterile as a heap of cinders or as the material in the roadway.

Nitrification.—The most important work done by these soil bacteria is to bring about the production of ammonium salts and convert them into nitrates. These bacteria are most active at a temperature of 86° F. (30° C.) according to some authorities, and at 98° F. (37° C.) according to others, and become less active as the temperature rises above or falls below these points. It follows from this that nitrate-producing bacteria manufacture more plant food during the summer months, when the temperature of the soil is about 20 degrees warmer than in winter. This is just as it should be, for plants require far more nourishment when in an actively growing state in summer than when in a comparatively inactive condition in winter.

This wonderful nitrifying process is perhaps brought to the highest state of activity under glass at almost any season of the year. The temperature is raised by artificial means, and plants are "forced" into growth. This simply means that the bacteria respond to the higher temperature and the moisture, and proceed to attack the substances in the soil and place them more readily at the disposal of the crop. If the temperature is suddenly reduced the plants are said to "catch a chill"

and cease to grow. The sudden change from say 80° to 50° F. would injure the active bacteria and put them completely out of action, with the result that food supplies are immediately cut off from the plants. One of the great problems the cultivator has constantly before him therefore is to maintain just the temperature to promote the greatest activity amongst the soil bacteria. The grower under glass succeeds in doing this often at a great cost; but the open-air grower must make use of hot beds and plenty of good manure to achieve favourable results.



Forms of Bacterial Cells

1, Coccus. 2, Bacillus. 3, Vibrio. 4, Spirillum.

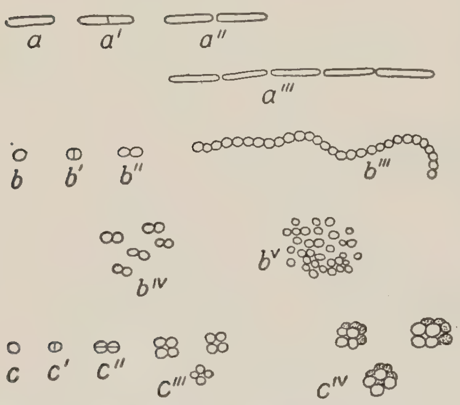


Fig. 90.—Diagrammatic Representation of the Methods of Vegetative Reproduction among Common Bacteria

a, A bacillus successively dividing at a^{I}, a^{II}, and a^{III}. *b*, A coccus giving rise to chains, b^{III} (*Streptococci*); pairs, b^{IV} (*Diplococci*); and irregular groups, b^{V} (*Staphylococci*). *c*, A coccus giving rise by division in two directions to c^{III} (*Micrococci*), and by division in three directions to c^{IV} (*Sarcinæ*).

There are several kinds of nitrate-forming bacteria in properly cultivated soils, amongst the best known to scientific research being *Bacillus mycoides*, *B. mesentericus vulgatus*, *B. subtilis*, and *Proteus vulgaris*. With a proper supply of organic manure, a certain amount of lime to check acidity, a genial temperature, and a deeply worked soil these bacteria render valuable services.

In *The Standard Cyclopædia of Modern Agriculture* we are told that "bacteria have a very simple structure—a speck of living protoplasm surrounded by a capsule or cell wall. They are unicellular, and are the smallest living organisms known, some being less than $\frac{1}{25000}$ in. in diameter. Although there are hundreds of different species, there are only three general forms—the spherical (termed a *coccus*), the rod-shaped (termed a *bacillus*), and the spiral (termed a *spirillum*). A curved rod is termed a *vibrio*." Professor W. B. Bottomley once humorously classified the three kinds—billiard balls, cigarettes, and corkscrews. The diagrams (fig. 90) illustrate the various forms and the methods of vegetative reproduction.

A single bacterium dividing in two, and taking one hour for the completion of the process, will in twenty-four hours produce 16,000,000 under suitable conditions. In ordinary cultivated soil the number of bacteria varies from 300,000 to 10,000,000 per gramme of soil (100 gm. = 3·527 oz. avoir.). They occur in the greatest number in the first 6 in. of the soil; below this they rapidly diminish until at a depth of about 3 ft. very few are to be found. Professor Hilgard, of the Californian

University, states that in a black loam with a considerable amount of humus there were 33,931,747 bacteria to 1 cub. cm., and as many as 53,596,060 in 1 cub. cm. of similar soil containing more humus. As there are over 16 cub. cm. to 1 cub. in., and 1728 cub. in. to 1 cub. ft., one can scarcely realize the teeming millions of bacteria there must be in a fertile soil. Most cultivators will accept Professor Hilgard's figures to save the trouble of counting them themselves. Speaking generally, the bacteria may be classed into three groups: (1) The "decomposition" bacteria, that attack and bring about the decay of manure and other organic matter; (2) the "nitrifying" bacteria, consisting of two distinct organisms: the one (*a*) *Nitrosomonas*, which converts ammonia into nitrous acid and nitrite; the other (*b*) *Nitrobacter*, which changes nitrites into nitrates; and (3) the "nitrogen-fixing" bacteria (*Azotobacter*), which absorb free nitrogen from the air and fix it in the nodules of the roots of leguminous plants.

Soil Inoculation.—It has been known from the earliest times that leguminous plants (Peas, Beans, Clovers, Vetches, &c.) had a beneficial effect upon cultivated soils—crops of a different nature grew better after a leguminous crop. But it was not until 1886 that Hellriegel discovered how the nodules on the roots of leguminous plants were really storehouses of nitrogen-fixing bacteria, and further investigations are being made by other scientists.

Arising out of these discoveries Professor Bottomley conceived the idea that, as the bacteria could be cultivated and isolated and kept for a long time under certain conditions, it would be possible to "inoculate" a barren soil—a heap of slag or clinker even—and bring it into a fertile condition by the aid of these bacteria, and especially one called *Bacillus radicicola*. In this way the "nitrogen famine", predicted by Sir William Crookes a few years ago at a meeting of the British Association, was to be staved off.

Experiments in "soil inoculation" have been carried out more or less carefully in several places, chiefly by non-cultivators, but it is not possible to draw any definite conclusions from them. But one thing at least appears to have been demonstrated by experiments carried out by Professor Nobbe, of Germany, and that is, that the nodule bacteria are likely to become overfed and lazy if there is already a good supply of nitrogenous food at their disposal in the soil; whereas, if there is a deficiency, it excites them into greater activity and virulence, exactly as if they were millionaires on the one hand and peasants on the other.

The practical lesson to be learned from these investigations would appear to be that (1) it would be a mistake to apply nitrogenous manures to leguminous crops in any great quantity, as they would prevent the healthy working of the bacteria; and (2) as the soil bacteria generally are in greater numbers in the first six inches of soil, they could be utilized to fertilize or inoculate the soil to a greater depth by trenching the soil, and burying the top spit, containing the trillions of bacteria, lower down. The subsoil rich in mineral foods (see p. 111) but lacking in bacteria,

would thus become a medium in which the bacteria would exercise their activity and virulence to the utmost. That is a far more simple and expeditious method of inoculating the soil than cultivating the bacteria in gelatine or powder. One crop of Broad Beans, French Beans, Clover, or Peas would produce trillions upon trillions of nitrogen-fixing bacteria to the acre in the top spit in the course of a season, and cultivators would do well to bear this fact in mind.

Denitrification.—This is the term applied to denote that the nitrates in the soil have become changed into free nitrogen. The nitrates thus become lost. Denitrification is said to be due to certain bacteria, just as the production of nitrates is due to other bacteria. Curiously enough, some scientists say that if air is admitted to the soil nitrogen is set free from the organic matter; and, on the other hand, if air is excluded, nitrogen is set free from the nitrates; and in both cases it is lost.

These views would appear to be mutually destructive. All good cultivators know from experience the great advantages to their crops arising from allowing a free circulation of air amongst the soil particles and organic matter, and the more thoroughly these are mixed the better the results. Growers of plants in pots always make a point of thoroughly mixing the various ingredients of their special composts so as to secure as much evenness or homogeneity as possible throughout. In field and garden, however, this work, although possible, is rarely practised. And it sometimes happens that enormous quantities of manure are dug or ploughed into a soil which already contains a good and sufficient supply of organic material. In such cases it is possible that, owing to the soil being as it were surfeited or gorged with manure, certain bacteria attack the organic material with the object of releasing the superfluous supply of nitrogen. It has already been shown at p. 110 that even a soil that has been unmanured for fifty years still has a fund of 2500 lb. of nitrogen to the acre at 9 in. deep—just in the region where the nitrate-forming bacteria are most numerous.

In support of the view that overdosing the soil with manure may result in the loss of nitrogen, the following experiments at Rothamsted may be quoted:—

I. Plot 7; Receiving Ammonium Salts (Containing 86 Lb. Nitrogen and Minerals)

	lb. per Acre.
Nitrogen originally present in 1865 (·1170 per cent) ...	3034
Nitrogen supplied in manure, 1865–93	2408
Nitrogen supplied in rain, 1865–93	140
Nitrogen supplied in seed, 1865–93	56
Total nitrogen expected, 1893	5638
Nitrogen removed in crops, 1865–93	1932
Nitrogen found in soil, 1893 (·1146 per cent)	2971
Total nitrogen accounted for in 1893	4903
Leaving nitrogen unaccounted for	735
	5638

II. Plot 2b; Receiving Dung (14 Tons, Containing 200 Lb. Nitrogen a Year)

	lb. per Acre.
Nitrogen present in 1865 (·1752 per cent)	4,343
Nitrogen supplied in manure, 1865–93	5,600
Nitrogen supplied in rain, 1865–93	140
Nitrogen supplied in seed, 1865–93	56
Total expected in 1893	10,139
Nitrogen removed in crops, 1865–93	1,484
Nitrogen found in soil, 1893 (·2132 per cent)	4,976
Total accounted for in 1893	6,460
Leaving nitrogen unaccounted for	3,679
	10,139

It would be difficult to find clearer examples of overdosing a soil with food it did not require. In one case (Plot 7), leaving out the unavoidable supplies from the rain and seed, 2408 lb. of nitrogen were given to a soil already containing 3034 lb. Almost twice as much as the crop needed! In the other case 5600 lb. nitrogen were given to a soil still richer in the same food (4343 lb. per acre). But in this case, the greater the overdose the smaller the quantity removed by nearly 500 lb.

That the loss of nitrogen was due mainly to overdosing seems to be still further proved by the experiment on the unmanured plot, the figures for which are as follows:—

Plot 3; Unmanured, 1865 to 1893

	lb. per Acre.
Nitrogen originally present in 1865 (·1050 per cent), top 9 in.	2722
Nitrogen supplied in manure, 1865–93	0
Nitrogen supplied in rain, 1865–93	140
Nitrogen supplied in seed, 1865–93	56
Total expected in 1893	2918
Nitrogen removed in crops, 1865–93	476
Nitrogen found in soil, 1893 (·0940 per cent)	2437
Total nitrogen accounted for, 1893	2913
Nitrogen not accounted for	5
	2918

It would appear from these experiments that it is just as unwise to give plants more food than they require in a given time as it is to gorge animals with a certain diet. The system cannot absorb it, and the body suffers in health in consequence. It would be interesting to have had some information as to the cultural details carried out at Rothamsted, the depth of culture, distance apart, and the yield per acre.

§ 11. STERILIZING SOILS

Of late years growers of Ferns, Cucumbers, Tomatoes, &c., have been much concerned as to the best means of rendering their plants immune from attacks of eelworm and other pests. The soil has been regarded as the seat of all the mischief, and various nostrums have been boomed as infallible remedies against all the diseases that attack market crops. At first some of these remedies appeared to check the disease, but after a time the trouble was as rampant as ever. The only things that have not been tried are cultivation and common sense. Soils have been brought into cucumber houses at great expense, and have been dosed with rich organic and chemical manures to such an extent that acidity becomes one of the predominant features. Under a high temperature, 85° to 95° F. and more, and an excessively humid atmosphere, trillions of bacteria are brought into being. Bearing in mind what has been said at p. 127 about nitrate-forming bacteria growing lazy owing to having too much nitrogenous food at their disposal, it is not to be wondered at that they fail to perform those beneficial duties which they carry out in a soil containing only a reasonable amount of organic material. Other bacteria, no doubt, then come into play and doubtless devour the lazy ones, and bring about such a condition of the soil that other troubles, like eelworms, arise and play havoc with the roots of plants.

This being the case, the simplest plan would appear to be to keep the soil from becoming acid by giving less rich food and more lime—the latter not only to counteract acidity, but also to induce the beneficent bacteria to carry on their work. In addition to this, plenty of fresh air must be admitted when possible, according to the state of the weather, because the bacteria must have fresh supplies of oxygen to encourage their activity. Many plant houses are so poorly ventilated that they become "stuffy" with the stale atmosphere in them.

Burning and Steaming the Soil. — Where a rational system of cultivation is not practised, recourse is had to steaming or burning the soil. Many growers of Ferns, for example, place the soil in receptacles of some kind, and have it burned in the furnaces before sowing spores upon it. The idea is that the excessive heat kills all the "bad" or unfriendly bacteria and leaves the good or friendly ones intact. It has been stated that bacteria are killed outright at 195° F., and that they cease to work, and become comatose or unconscious, at 132° F. Consequently, when soil is heated to 200° or 300° F. it follows that the bacteria must be killed right out, and the soil reverts to a more or less sterile condition. Because, in addition to killing the bacteria, if the heat is too intense all organic material will be driven off also, leaving only the mineral substances of the soil. This result can be achieved without burning, simply by crushing pieces of brick or mortar, and sowing the spores upon them, as many growers do.

A MIDDLESEX MARKET GARDEN AT DAFFODIL TIME

Photos. by Chas. L. Clarke

A CITY OF GLASSHOUSES AT WALTHAM CROSS, NEAR LONDON

Steaming the soil would have rather a different effect from burning. The bacteria would be killed, but the organic material would remain; but whether it would retain all its nitrates and other foods or not experiment only could prove.

Comparing the methods of growers who "sterilize" their soils with those who do not, the latter produce at least as good crops as the former, if not better, and without incurring further expense. Generally speaking, if soils before use are well exposed to the action of the weather, and are not afterwards overdosed with strong manures, they will continue to yield excellent results.

§ 12. ELECTRIFYING THE SOIL

From time to time scientists have turned their thoughts to the question of electricity in connection with the soil and plant growth, and numerous experiments have been carried out. The main object of these experiments is to try to rob the atmosphere of nitrogen and convert it into nitric acid, in the hope that plants will not only grow bigger and better but much quicker than at present. The actual cultivation of the soil itself on scientific principles does not appear to have been considered in these experiments, all of which seem to aim at getting as much out of the soil as possible without having recourse to physical labour. When it is remembered that a man who digs 1 ac. of ground 1 ft. deep turns over about 1340 tons of soil in 10 to 14 days (more or less) at a cost of a couple of pounds, the idea of the "electrical" cultivator is apparently to save this trouble and expense.

Amongst those who have already taken part in electrifying the soil are the French priests the Abbé Berthelon and the Abbé Nolet, the Swedish Professor Lemström, and, more recently, Sir Oliver Lodge and Mr. J. E. Newman, of Evesham. Under the Newman-Lodge method—as *The Times* describes it—"the wire is taken from the dynamo to a shed in one of the fields which are to be electrified. This shed contains apparatus for transforming the electricity to high tension, and also the vacuum valves. The network over the crops consists of a kind of gridiron of wire, supported from each pole with larger insulators than those seen on telegraph poles. The poles are 70 yd. apart in the rows and 100 yd. apart between the rows. The thick telegraph wire is extended down the rows, with thin wire—to encourage leakage—at every 10 yd. The thin wire is invisible 20 yd. off. There is a slight fizz, caused by the electrical discharge, and in walking beneath the wires a slight sensation may be experienced. At night there is some glow. If a wire breaks —this does not often happen—anyone picking it up would receive an unpleasant shock; but though there are obviously possibilities of electrocution in the high-tension shed, there is no risk to life in the field. The apparatus does not supply a tenth of an ampere. The apparatus can

be managed by a boy, but it is necessary to make sure from time to time that there is no interference with the proper discharge of the electricity due to leakage down damp poles or to defective insulators. An installation of the simplest type, for experimenting on from 5 to 10 ac., a dynamo being available, would probably cost about £100. In the same conditions an installation for 60 ac. might cost about £225. A complete outfit for 30 ac., including engine, dynamo, and shed, would involve an expenditure of something like £300, but an installation for twice the area would not cost more than another £100. There is a probability of the expense being decreased in the future." It is claimed for this electrical process that there is an increased yield accompanied by accelerated production, and the plants (Lettuces have been chiefly experimented on) are of a deeper green.

It is always wise to pay attention to experiments, even when carried out by those who have had little or no training in horticultural practice, but we have no hesitation at present in saying that £6 or £8 per year spent on trenching an acre of ground 2 ft. to 3 ft. deep would yield larger supplies of nitrates and crops immensely superior to anything that can be achieved by "electrical" culture. [J. W.]

§ 13. SOIL ANALYSIS

All growers, whether amateur or professional, are aware of the difficulty of estimating just what form of plant food is deficient, and usually it is only by more or less costly experiments that some basis can be obtained. Of course many men simply depend on certain quantities, adding such to the soil whether the plants require it or not, until soil sickness occurs, and, in consequence, many pests and plant diseases.

To obviate the above disadvantage, and to obtain a useful knowledge of the composition of the soil, analysis, both chemical and physical, is resorted to, and it is proposed to deal with this in as simple a way as possible. It must of course be thoroughly understood from the beginning that to arrive at an accurate analysis requires much expensive apparatus as well as a long course of practice and study, but enough information will be given to enable the studious grower to obtain many useful data, to save him from wasting his time over unnecessary experiments, and also to open a new field for research and profit.

In the older methods of analysis the soil after preparation was digested by strong acids, hydrochloric being the chief. This extracted all the food that might or might not be available at some future period, but gave no idea of what was immediately available for the plant's use. In consequence of this the results were so misleading that soil analysis was spoken of with scorn. Often enough one ingredient was said with truth to be in large quantity, but the growing crop would show symptoms of starving for want of that very constituent. As an instance, clays and clay

loams are usually designated as being rich in potash, yet the addition of potash salts will often give high results on such soils, showing therefore a deficiency in available potash, an entirely different thing from total potash.

Many of the food salts in the soils are so tightly held or combined as to resist even long years of cultivation and weathering.

Nowadays it is the rule to dissolve out the available salts which can be immediately rendered available to the growing crops, by using for this purpose a 1-per-cent solution of citric acid; this strength having been estimated to correspond with the solvent action of natural forces at work.

These forces are the weak organic acids obtained from humus, the work done by the beneficent and other bacteria, as well as by enzymes and certain fungoid moulds, and, lastly, by the solvent action of soil water impregnated with carbonic acid gas.

It is not at all necessary for anyone to attempt a complete analysis. To obtain such would mean probably months of work, and the data obtained would be of very little value to the grower. What is usually done is to give the quantities of lime carbonate (chalk), magnesia, nitrogen, phosphates, potash, the total contents, organic matter and humus.

About 40 to 80 per cent of soil matter is inert and does not enter into the fertilizing, but its composition determines the physical condition of a soil and thus has a great bearing on cultivation.

In reading an analysis care should be taken to note that the magnesia, usually magnesium oxide (MgO), is not in excess of the lime contents, or disease and various other troubles will quickly follow. It will not matter how much lime carbonate is present if the magnesium oxide is multiplied by 2 and then compared with lime carbonate. Sufficient of the latter must be added to give a proportion equal to four of the former (magnesium carbonate) to seven of the latter (lime carbonate).

A sample of soil may be taken as follows: Cut a square about 9 in. with a spade to a depth of about 1 ft.; take the whole of the soil from this block and place in a box. Remove to a shed or laboratory for examination.

If the soil is rather wet, allow it to air-dry somewhat, and then work through a fine sieve to remove all stones. Take a portion of the soil, say $\frac{1}{4}$ to $\frac{1}{2}$ lb., and place in a beaker, tube, or even an ordinary jug. Fill the vessel containing the soil three parts full with water; stir to a paste, thus separating clay from sand. Allow to settle somewhat, pour off, and repeat this until the added water becomes no longer turbid. Remove the sand from the bottom, air-dry, and weigh, and the result will show you into what class your soil fits, whether it be sand, sandy loam, loam, clayey loam, or clay, the physical constituents of which are given at p. 92.

Chemical Analysis.—The following is a minimum list of apparatus, some of which may be evolved from ordinary articles in everyday use, but

the majority will need to be specially designed, or accuracy in results cannot be looked for:—

1 balance.
Palette knife.
Beakers. 6 at 300 cub. cm. capacity.
,, 2 at 600 ,, ,,
1 Winchester quart for citric digestion.
CO_2 apparatus.
2 Berlin porcelain dishes, 4 in.
4 ,, ,, crucibles.
1 distilling flask and condenser.
1 closed vessel to supply steam, to act as small boiler.
2 conical flasks with Bunsen valve.
2 burettes, 50 cub. cm.
1 pipette, 25 cub. cm.
1 graduated measure, 500 cub. cm.
1 ,, 100 ,,
6 clockglasses.
2 filtering funnels, 4 in.
2 filtering funnels, 6 in.
1 stoppered cylinder, 750 cub. cm.
1 desiccator
1 wash bottle for water.
1 ,, ,, alcohol.
1 ,, ,, ammonia.
1 ,, ,, hydrochloric acid.
1 ,, ,, nitric acid.
1 pestle and mortar.
6 glass rods.
1 large sieve, 4 meshes to inch.
1 small ,, 16 ,, ,,
Filter stand.
Water bath.
,, oven.
Burette stand.
Filter papers.
1 pair crucible tongs.

Lime Carbonate.—The first constituent to be estimated will be the lime carbonate in the soil. Proceed as follows: Place a small quantity of soil in a test tube or other convenient vessel, such as a cup; fill up to 1 in. from bottom; pour over sufficient strong hydrochloric acid (commercially known as spirits of salt) to cover the soil. If the soil contains a reasonable amount of lime carbonate a vigorous effervescence will occur, but if there is little or no disturbance then lime or lime carbonate must be added to the soil at once. The chemical action is roughly as follows: Hydrochloric acid (HCl) attacks the calcium carbonate ($CaCO_3$), driving out carbonic acid gas and forming calcium chloride.

The more accurate method adopted by chemists is as follows:—

To estimate the available constituents of the soil, 200 gm. are mixed with 2000 cub. cm. of 1-per-cent citric acid solution and left for a week, the whole being shaken up once a day. The solution is then filtered and divided into separate portions of 500 cub. cm.

Phosphates.—To estimate the soluble phosphates 500 cub. cm. are evaporated until the volume is reduced to about 100 cub. cm. and then allowed to cool, and 40 cub. cm. of ammonium molybdate solution added, well stirred, and allowed to stand in a warm place. This is then filtered and the precipitate washed, first with dilute nitric acid and then with very small quantities of distilled water. The precipitate is then dissolved in ammonium hydrate and 20 to 30 cub. cm. of magnesia solution added, the whole being allowed to stand for twelve hours for complete precipitation. The resulting precipitate is now filtered off and washed with dilute ammonia dried and incinerated in a crucible, the residue being

weighed as magnesium phosphate. From the magnesium pyro-phosphate obtained the weight of phosphoric acid can be calculated. One part of magnesium pyro-phosphate = ·64 parts of anhydrous phosphoric acid (P_2O_5).

Total phosphates are estimated by treating 5 gm. of dried soil with 25 cub. cm. of concentrated hydrochloric acid, and evaporated to dryness over a water bath. The residue is moistened with concentrated sulphuric acid, then treated with a mixture of 10 cub. cm. of hydrochloric acid and 10 cub. cm. of water, warmed, filtered while hot, the filter paper being well washed, and the filtrate treated with an excess of ammonia, boiled, allowed to cool, and filtered. It is then redissolved in nitric acid and dried with 40 cub. cm. of ammonium molybdate exactly as indicated in the paragraph above for soluble phosphates.

Potash.—To estimate the potash a further 500 cub. cm. of the citric acid solution are evaporated to dryness and incinerated in a basin over a Bunsen burner to eliminate the organic matter. The residue is then treated with boiling distilled water and filtered. An excess of platinum chloride is then added to the filtrate, and the whole is slowly boiled until nearly dry. The precipitate is filtered off and washed with alcohol until no yellow coloration is to be seen in the filtrate. The least possible quantity of water is then added, together with an excess of magnesium powder. The reaction with this is completed by boiling. After cooling, the excess of magnesium is dissolved in hydrochloric acid, the whole being filtered and the precipitated platinum, which remains upon the filter, is washed free from acid, dried, and weighed. From this platinum is calculated the quantity of potash present. One part of platinum = ·48 parts of potash (K_2O).

Iron.—Available iron is estimated in a further 500 cub. cm. of citric acid solution, this being evaporated to dryness over the water bath, and incinerated over a Bunsen burner to drive off the whole of the organic matter. The residue is dissolved in hydrochloric acid, then evaporated in a conical glass flask. The iron is reduced to the ferrous condition by the addition of metallic zinc (adding only sufficient to get it into complete solution), and titrated with a deci-normal permanganate of potash solution. Each cubic centimetre of permanganate of potash required until permanent coloration is produced indicates the presence of ·008 gm. of Fe_2O_3 or ferric oxide.

Calcium Carbonate.—This is estimated by 5 gm. of the dried soil in a CO_2 apparatus, one portion of which contains a supply of hydrochloric acid and a tube to enable it to be passed into the portion containing the soil, and a further portion contains a tube filled with concentrated sulphuric acid through which the escaping gases pass, in order to retain in the apparatus any moisture that may tend to be carried away. In this way the calcium carbonate is decomposed, the carbon dioxide being evolved. The apparatus is then stood for a quarter of an hour on the water oven to ensure the exclusion of the whole of the gas. The weight of the whole apparatus being taken, with the soil in it, before commencing the operation, it is now weighed again and the difference represents the

loss of CO_2 gas. 44 parts of the gas represent 100 parts of calcium carbonate that was present. This assumes that there is no magnesium carbonate present.

Humus.—In estimating the humus, 10 gm. of dried soil are taken and washed on the filter paper with a 1-per-cent solution of hydrochloric acid till free from calcium salts. It is then well washed with hot, distilled water till free from acid, and washed into a long stoppered cylinder with 500 cub. cm. of 4-per-cent ammonia solution. It remains in the solution twenty-four hours, allowing the cylinder to lie in as nearly a horizontal position as is possible without allowing the stopper to leak, and is well shaken at intervals. The cylinder is then stood upright for twelve hours to allow the whole to settle to the bottom. The solution is then filtered, and 100 cub. cm., representing 2 gm. of soil, are taken and evaporated to dryness over the water bath. The dish is then placed in the water oven for a few minutes, to dry off any adhering moisture, and weighed. After weighing, it is incinerated until all the organic matter has burned off. The dish is allowed to cool in the desiccator and the weight again taken. The difference in the weights before and after incineration gives the humus.

Magnesia.—This is estimated by boiling 5 gm. of dried soil with 25 cub. cm. of concentrated hydrochloric acid, and evaporating to dryness over a water bath. The residue is moistened with concentrated sulphuric acid, then treated with a mixture of 10 cub. cm. of hydrochloric and 10 cub. cm. of water, warmed, filtered while hot, the filter paper being well washed, and the filtrate treated with an excess of ammonia, boiled, allowed to cool, and filtered. The filtrate is neutralized with acetic acid and treated with ammonium oxalate (about 20 cub. cm.) to remove calcium, and again filtered. The filtrate is evaporated down and treated with successive 5-cub.-cm. lots of concentrated nitric acid to eliminate ammonia salts. As the liquid by this time has evaporated down to a small bulk, it is diluted to about 200 cub. cm., treated with ammonium phosphate, and allowed to stand for twelve hours. It is then filtered and washed with dilute ammonia, dried in the steam oven, and incinerated in a crucible and weighed. From the weight of magnesium pyro-phosphate obtained the magnesia can be calculated as MgO. 1 part of magnesium pyro-phosphate = 36 parts of magnesia oxide. [C. P. C.]

SECTION V

Manures and Manuring

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§ 1. INTRODUCTORY

The word "manure" has now come to mean any substance that is placed on or in the soil with the object of fertilizing or enriching it in plant food. Originally the word meant "working with the hand", having been derived from the two French words *main*, the hand, and *œuvre*, work. There is a vast depth of meaning in the word "manure", if the French derivation of it is accepted. Long before botanical or agricultural science enabled man to understand the nature of his plants, and what they required as food, the peasant who tilled his ground by hand was manuring or "manœuvring" it in the real sense of the word. And even to this day, "working" the soil—turning it up and exposing it to the weather—is one of the cheapest and best, if not the quickest, methods of adding fertility to the soil.

Since, however, the great and illustrious Baron Justus von Liebig (b. 1803, d. 1873) propounded his theories on agricultural chemistry some seventy years ago, a vast change has taken place in the methods of manuring. The chemist has stepped in, and as a result of his laboratory experiments he has told the gardener and the farmer, but chiefly the latter, what manures he must use if he would wish to obtain the best results from his soil. A vast industry has arisen in the shape of chemical or artificial manure manufacture, and thousands have become impressed with the idea that their salvation as cultivators depends entirely upon the amount of "artificials" they apply to their soil. Indeed, there is very great danger of the art of cultivation being lost altogether amongst the agricultural community, and even amongst many market gardeners.

Cultivators of the soil should always remember the very old story of the dying man who on his deathbed told his sons that they would find gold deeply buried in the farm, and they had only to dig deep enough to obtain it. At first the sons mistook their father's meaning, and it was not until they had turned up the soil of the farm to a great depth, and noticed the magnificent crops that followed, that they began to realize the true meaning of their father's words. The gold came, not as they expected, from the soil itself, but from the sales of their farm produce.

If they had not tilled the ground deeply the gold would not have been forthcoming in any shape or form.

This story conveys an excellent moral for all cultivators, and it embodies the true principles of manuring—principles that are strictly in accordance with all we have learned about the composition of soils and manures from the best scientific authorities.

Experiments at Rothamsted and elsewhere clearly prove that the soil does contain vast supplies of some of the most important plant foods, such as nitrogen, phosphates, potash, lime, magnesia, soda, iron, chlorine, silica, &c. But what none of these experiments teach is that these foods can be liberated and made available for the use of our various crops by cultivation or "handworking" the soil.

After all, it must be remembered that the agricultural chemist is not a cultivator, although he may deduce from the chemical analysis of a certain soil, or a certain plant, that such and such foods are required, and that it is only necessary to supply them by means of some artificial manure, and the plant will proceed to carry out its functions, and be perfectly happy ever after.

If this were really the case, the art of manuring would be reduced to the simplest mechanical process. A certain soil is found by analysis to be lacking or deficient in one or more foods that we know to be essential for the welfare of a certain crop. Therefore sprinkle over the soil—or dig it in—a manure which is known to contain the necessary foods, and all will be well—at least it was thought so at first by Liebig and others. The quantity of special fertilizer must be carefully regulated, otherwise the plants, instead of growing, will probably die. Indeed the difficulty as to regulating the quantities to be applied has only been overcome by frequent experiment, and after plants had been killed by overdoses.

This is practically the basis upon which modern manuring is practised. Either the soil is dosed with special manures, or certain crops are given special manures, almost irrespective as to their growth, or as to the nature and condition of the soil in which they are growing.

If these principles of manuring were sound, our cereal and root crops ought to show a vast increase in yield and quality since farmers have taken to using artificial fertilizers in such large quantities. But our crops of wheat, oats, barley, rye, potatoes, turnips, beet, mangels, Swedes, &c., appear to be no greater *on the average per acre* now than they have ever been. Here and there, of course, are to be found exceptions that prove the truth of the statement, but it will generally be found that these exceptions are due more to good cultivation—to the working, and cleansing, and purifying of the soil—than to the extensive use of artificial fertilizers.

This view receives confirmation from Prof. Snyder, of the University of Minnesota, in his book on *Soils and Fertilizers*. He says: "Scant crops are as frequently due to the want of proper tillage as to the absence of plant food. Poor cultivation results in getting the soil out of condition; then instead of thoroughly preparing the land, commercial fertilizers are

resorted to, and the conclusion is reached that the soil is exhausted, when in reality it is suffering for the want of cultivation, for a dressing of land plaster, for farm manures, or for a change of crops. There is no question but what better tillage, better care and use of farm manures, culture of clover, and systematic rotation of crops would result in greatly reducing the amount annually spent for commercial fertilizers without reducing the yield of crops, as well as securing larger returns for the fertilizers used. In general, the better the cultivation the less the amount of commercial fertilizer required for average farm crops. Cultivation cannot, however, entirely take the place of fertilizers."

The reader must not imagine that artificial manures are being abused. From practical experience the writer knows their virtues very well, but the point he wishes to drive home is that artificial manures, unless used carefully and judiciously, are more likely to ruin a cultivator than to add to his bank balance. They have their uses undoubtedly, and as adjuncts to natural manures and cultivation they can be made to play a most important part. Many experimenters and growers are beginning to realize this now, and they take care to use a proper mixture of natural and artificial manures.

Misleading Experiments.—Perhaps the most misleading thing about the application of certain manures in experimental gardens is that what is found to yield good results in one particular soil may prove to be quite useless on another soil. If the increased yield in a crop could be really attributed to the application of a certain manure, the experiments would be of immense value. A reference to the article on the "Manuring of Potatoes", in Vol. IV, will, however, convince any cultivator that no real reliance can be placed on a particular manure applied to any soil. It will be noticed from the figures that the very manures which are claimed to yield large crops in one county are the very same that give results even poorer than the soil to which *no manure at all* has been applied. If it is fair to claim an *increase* in yield for certain manures in one place, it is equally fair to attribute a *decrease* in yield to the same manure applied in another locality. And yet all manurial experiments are carried out on this illogical basis. The only reliable thing about the application of special manures is that results are true only for the particular place in which they are obtained.

Another misleading method of applying manures is to assume, first of all, that a certain crop requires certain manures, and must have them at all costs. Take, for instance, such a crop as the Turnip, which is said to take up 112 lb. of nitrogen, 33 lb. phosphoric acid, and 148 lb. of potash from an acre of soil. The uninitiated are apt to come to the conclusion that large supplies of nitrates, phosphates, and potash must be applied to the soil, no matter what its chemical or physical condition may be, whenever Turnips are to be grown.

Some laboratory experimenters, indeed, make a difference between "light" and "heavy" soils, and recommend a variation in quantity of

the manures which analysis has indicated as being essential for a certain crop. It is, of course, possible that such recommendations will prove effective in certain cases, but that will be more by accident than design, and will depend upon circumstances.

Before applying special manures to the soil the cultivator has to consider, first of all, the physical nature of his particular soil; the amount of manure, organic or otherwise, he has already given it; the crops grown and harvested from it; and the system of cultivation practised, whether deep or shallow. He must also remember that every cultivated soil, even one that has not been manured for fifty years, like that at Rothamsted, contains almost inexhaustible supplies of certain foods. His main object ought to be to bring as much of this food supply as possible into use by good and deep cultivation, and then to supply *the deficiency* (if any) by organic or inorganic manures, or by both in certain proportions. This is the wise and economic policy to pursue, and it will pay much better to turn up the soil to a good depth than merely to scrape up a few inches of the crust, which has been perhaps cropped over and over again for years until it has become either sick or exhausted.

In business the grower must pay from £4 to £20 and more per ton for special manures to supply food which probably exists in abundance in his own soil if he would only liberate it. A ton of special artificial manure, costing say £20, will dress from 3 to 7 ac. The same amount of money spent in digging the soil 1 ft. deep would bring from 7 to 10 ac. into a fertile condition, or, if double dug, from 3 to 5 ac., with more lasting effects. The insoluble stores of nitrogen, phosphates, potash, and lime that are locked up in it in the dark are likely to be liberated and made available when brought up to the light and exposed to the action of the weather. Indeed, in actual practice it is so, and the man who turns his soil up most frequently and most deeply is the one who reaps the largest and best crops at a minimum of expense.

The point, therefore, for the commercial grower to consider is, which is better—to spend more money on labour and get his plant foods out of the soil, or to spend less money in labour and more in artificials and leave the natural food supplies in the earth untapped for many years?

The Object of Manuring.—The main object of manuring is to restore to the soil, in a more or less available form, the foods that have been taken out of it by the growth of crops. It is evident that if everything taken from the soil were again replaced, there would be no loss at all. But if all the crops grown were put back again, there would be far more material returned to the soil than ever came out of it. There is still a popular impression that the *entire weight* of a crop comes from the soil, and from the soil only. The air and water get but very little credit for the important part they play in providing, after all, by far the greater weight of every plant. Water itself may be looked upon not only as the means by which foods from the soil are drafted to all parts of the living tissues, but also as a distinct food or manure, as it supplies both oxygen and hydrogen.

Before we consider the application of manures to the soil it is necessary to refer again to van Helmont's experiment with the Willow, already described at p. 108. That experiment clearly proved that the great bulk of a plant's weight came, not from the soil, but from the air and from water. Carbonic acid gas (of which there are only 4 volumes out of 10,000 in the atmosphere) supplies all the carbon that is necessary, so long as the cultivator is sensible enough to allow his plants sufficient space and light, and does not overcrowd them. This carbon, which makes up the great bulk of the dry weight of every plant, is obtained absolutely free of charge from the air, and there is not the slightest danger of the supply becoming exhausted. The carbon from the air and the water from the soil make up from 95 to 99 per cent of the weight of all plants, thus leaving from 1 to 5 per cent of material to be provided by the soil alone. Perhaps this fact will be made more clear by the following analysis of the wheat plant, taken from Sowerby's *Thorough Cultivation*:—

COMPOSITION OF WHEAT PLANT

	Per Cent.		
Carbon	47·69	=	93·55 per cent of the whole plant obtained from the *air* and water.
Hydrogen	5·54		
Oxygen	40·32		
Soda	0·09	=	3·386 per cent of foods, which as a rule are present in large quantities in the soil (see p. 110), and have to be rarely applied artificially.
Magnesia	0·20		
Sulphuric acid	0·31		
Chlorine	0·03		
Oxide of iron	0·006		
Silica	2·75		
Manganese...	0·29		
Nitrogen	1·60	=	3·00 per cent of foods which the soil contains in limited quantities (see p. 110), and which must be rendered available by cultivation or supplied by manures.
Phosphoric acid	0·45		
Potash	0·66		
Lime	0·29		

From this table it becomes evident that the art of manuring the soil is narrowed down in a very remarkable degree. As with wheat, so with other crops. The cultivator has not to concern himself with providing oxygen, carbon, or hydrogen so long as he allows his plants plenty of fresh air and a proper supply of moisture. He is actually relieved of the burden of finding over 93½ per cent of the material which makes up his crops. The other 3·386 per cent, consisting of soda, magnesia, sulphuric acid, chlorine, oxide of iron, silica, and manganese, he also very rarely has to trouble himself about, as they are generally present in great quantities in the soil. But he *must* remember that those inorganic foods can only be liberated and brought into an available form by the constant use of the spade, the fork, the plough, the hoe, &c.; in fact, by cultivation or

tillage operations. If the soil is *not* cultivated, these foods remain dormant, inactive, and insoluble, and therefore worthless to any crop.

Having 97 per cent of the bulk of his crop practically provided *free of charge*, except for labour, the cultivator has to devote his energies to supplying the other 3 per cent, made up of nitrogen, phosphoric acid, potash, and lime. Now, the soil is by no means deficient in these foods. In the Broadbalk Field, Rothamsted, it has been found that a soil which *had been cropped, but had not been manured* for fifty years, still contained 2500 lb. of nitrogen, 2750 lb. of phosphoric acid, 6750 lb. of potash, and 62,250 lb. of lime to the acre at a depth of only *9 in.*

These figures are remarkable, and cultivators would do well to remember them. If a soil that has been cropped, but has been *unmanured for fifty years*, still contains such large quantities of the most important plant foods, it ought to follow as a matter of course that a soil which has been cropped and has also been *manured* for the same period should show far larger quantities of these particular foods. Such, however, is not the case, as the experiments carried out at Rothamsted prove. The addition of certain manures often has the effect of liberating too freely some of the plant foods, and as they cannot be absorbed by the crop, they are lost in some way, or at least cannot be accounted for (see p. 128).

To appreciate all the factors in the case it is necessary to remember what has been already emphasized, that only very small quantities of nitrogen, phosphoric acid, potash, and lime are taken from the soil. It has been estimated that fruit trees and ordinary farm crops take from the soil from 50 to 100 lb. of nitrogen, 20 to 50 lb. of phosphates, 30 to 150 lb. of potash, and 150 to 200 lb. of lime. Comparing the figures with the supplies still remaining in the Broadbalk Field at Rothamsted after fifty years, and with the supplies that are said to be in a fertile soil, it is evident that only small quantities are liberated as food for each crop. The usual deduction made is, that as these supplies of nitrogen, phosphates, potash, and lime are to be found in a soil after fifty years, therefore they are regarded as unavailable and probably useless. This view seems to be quite erroneous. Why should these vast supplies become immediately soluble? Would it not be a dire calamity if they were to become so, and if they vanished in one season? The result would be complete and absolute sterility, and succeeding crops would have to starve. Apart from this, it would be a physical impossibility for any crop to take up or absorb 62,250 lb. of lime, 6750 lb. of potash, 2750 lb. of phosphates, and 2500 lb. of nitrogen—altogether, 74,250 lb. (over 33 tons) per acre. In a Turnip crop weighing 33 tons, only about 2 or 3 per cent of the dry weight, say from 1400 to 2000 lb. would come from the soil, the remainder coming mostly from the air and water.

In the *Bulletin* (No. 103) of the Cornell University, U.S.A., for October, 1895, the following interesting figures appear in connection with an experiment on some Wagner Apple trees—thirty-five to the acre.

TOTAL WEIGHT AND CONTENTS OF ONE WAGNER APPLE TREE, THIRTEEN YEARS OLD, AND OF THIRTY-FIVE SIMILAR TREES TO THE ACRE

Total Weight.	One Tree.	35 Trees to Acre.
	lb.	lb.
Leaves	33·18	1161·3
Water	15·92	557·2
Dry matter	17·26	604·1
Nitrogen	0·29	10·15
Phosphoric acid ...	0·08	2·80
Potash	0·28	9·80

At the end of twenty years (the Apple trees being then thirty-three years of age) it was computed that the amount of nitrogen, phosphoric acid, and potash taken from the soil during the period of trial was as follows:—

	Nitrogen.	Phosphoric Acid.	Potash.
	lb.	lb.	lb.
Fruit	498·60	38·25	728·55
Leaves	456·75	126·00	441·00
Total for 20 years ...	955·35	164·25	1169·55
Average per year ...	47·76	8·21	58·47

These quantities are much less per acre per annum than those already given above. They serve, however, to indicate the small amount of food exhaustion that takes place, and incidentally the quantities of nitrogen, phosphoric acid, and potash that might have to be supplied to maintain the equilibrium of available foods in the soil. Assuming the figures to be fairly accurate, it would appear that the fallen leaves, if dug into the ground during the winter months, would supply, when rotted, about *half* the entire quantity of food taken out during the year, as shown, thus:—

	Nitrogen.	Phosphoric Acid.	Potash.
	lb.	lb.	lb.
Food taken from an acre of soil each year ...	47·76	8·21	58·47
Food supplied by fallen leaves per acre ...	22·83	6·30	22·00
Balance to be supplied by cultivation and manures per acre... ...	24·93	1·91	36·47

The quantities of nitrates, phosphates, and potash taken out of an acre

of soil each year naturally vary a good deal, according to the nature of the crop. It will be seen from the table below that some crops absorb much larger quantities of certain foods than others, and this fact should be borne in mind when applying manures.

Table showing in Round Numbers the Quantities of Nitrogen, Phosphoric Acid, and Potash taken out of an Acre of Soil by various Crops

Crop.	Nitrogen.	Phosphoric Acid.	Potash.
	lb.	lb.	lb.
Fruit crops	75	50	150
Mangels, 22 tons ...	138	53	300
Beets, 14 tons ...	68	31	142
Turnips, 17 tons ...	112	33	148
*Turnips, 17 „ ...	187	74	426
Swedes, 14 „ ...	98	22	79
Beans (30 bus. grain) and straw ...	106	29	67
Oats, 45 bus. and straw	55	19	46
Wheat, 30 „ „	48	21	35
Barley, 30 „ „	48	21	36
Maize, 20 „ „	43	18	36
Potatoes (6 tons, tubers)	47	22	76
*Potatoes (6 „ „)	119	55	192
Meadow hay, 1½ tons..	49	12	51
Red clover, 2 „ ...	102	25	83
Hops	200	85	134
*Cabbage	213	125	514
*Cauliflower	202	76	265
*Carrot	166	65	190
*Cucumber	142	94	193
*Lettuce	41	17	72
*Onion	96	49	96
*Pea	153	39	69

It will thus be seen that such crops as Mangels, Turnips, Beans, Red Clover, and Hops absorb large supplies of nitrogen from the soil; and Mangels, Turnips, Beet, and Hops also drain the soil of large quantities of potash. It is noteworthy that such leguminous crops as Beans and Clover should take up such large quantities of nitrogen, notwithstanding the power they possess of fixing the nitrogen of the atmosphere (p. 127).

The figures for the crops marked with an asterisk are taken from Professor S. W. Fletcher's book on *Soils*, and relate to analyses at the Michigan Agricultural College. It would appear that according to the climate, and no doubt the methods of cultivation, the quantities of food taken from the soil would vary very much.

§ 2. KINDS OF MANURES

Long before agricultural chemistry was thought of there were practically only two kinds of manure in use—farmyard or stable manure and lime. These constituted the stock of the farmer and market gardener, but other odds and ends were added to soil in the way of waste materials. With the advance of botanical and chemical science, however, plant-growers have been made aware of the different constituents of plants, and numerous experiments proved that from twelve to thirteen different ingredients (see p. 108) were always found in plants, and had to be supplied. Of these the most important are the nitrates, phosphates, potash, and lime. Hence manures are now classified in accordance with the amount of food they supply as nitrogenous, phosphatic, potassic, and calcareous. Natural manures supply all these foods in small quantities in proportion to their bulk, but they must not be despised on this account. The advantages of complete, bulky manures are discussed under the heading of "Farmyard Manure" below, and these advantages exist to a certain extent in all organic material placed in the soil for manurial purposes. Artificial manures, on the other hand, supply large quantities in proportion to their bulk of one or more fertilizers, and therefore have to be used with caution. And they possess not only this disadvantage, but others. They supply no humus to the soil, and consequently are incapable of generating bacteria. Their application is often of what may be termed a purging nature, because they liberate too freely large quantities of valuable foods that cannot be absorbed by the roots of plants, and are therefore lost either in the drainage or as gas that escapes into the air. Thus it may happen that a soil, instead of being enriched by applications of chemical manures, may be quickly impoverished and rendered sterile. In practice this is actually the case when chemical manures are applied injudiciously or indiscriminately.

From a practical standpoint it may be more convenient to consider the various manures under the following headings:—

1. *Complete Manures.*—Those supplying not only nitrogen, potash, phosphates, and lime, but also the other essential foods like sulphur, iron, magnesia, soda, chlorine, &c.
2. *Nitrogenous Manures.*—Those chiefly supplying nitrogen.
3. *Phosphatic Manures.*—Those chiefly supplying phosphoric acid.
4. *Potash Manures.*—Those chiefly supplying potash.
5. *Calcareous Manures.*—Those supplying lime or chalk.
6. *Miscellaneous manures*, such as sulphate of iron, salt, &c.

§ 3. COMPLETE MANURES

Farmyard Manure or Dung.—This name is applied to solid and liquid excreta from animals, together with the litter that has been used for bedding down. Wheat straw is generally used for litter, but peat-moss litter has of late years become a rival for bedding in stables. Other materials, such as bracken, shavings, spoiled hay, &c., are used also; but whatever material is used it becomes farmyard manure when it becomes too wet with urine and too foul with droppings to be used any longer for bedding. It is then taken outside and stacked in heaps. The urine of animals being usually richer in nitrates, phosphates, and potash than the droppings, every care should be taken to preserve it, not only for its intrinsic value as a fertilizer, but because it is useful for keeping the litter in such a state of dampness that it will not burn or turn mouldy. Wheat straw will absorb about three times its own weight of liquid, and peat-moss litter about eight times its own weight. It has been estimated that a horse affords 1000 lb. of urine annually containing 89 lb. of solid matter, and a cow 13,000 lb. of urine containing 1023 lb. of solid matter. About 67 lb. of solid matter is contained in 1000 lb. of human urine; 21 lb. in 1000 lb. of pig urine, and 30 lb. of solid matter in 1000 lb. of sheep urine.

The quantity and quality of the excreta vary according to the kind of animal, its age, and the food it eats. The droppings from cows and pigs contain more liquid than those from horses and sheep. Hence the "sloppy" manure from pigs and cows is termed cold, and is useful for "hot" gravelly or sandy soils. Horse and sheep manure, however, is known as hot, and is better applied to heavy or tenacious soils.

It has been estimated by a German scientist that a horse will excrete 28 lb., a cow 73 lb., a sheep 3·8 lb., and a pig 8·3 lb. per day, and that these excreta mixed with straw litter will yield 33 lb., 81 lb., 4·4 lb., and 12·3 lb. of manure per day from each animal respectively. This estimate is presumably for fully grown animals in a normal state of health.

Storing Farmyard Manure.—In most cases, perhaps, farmyard manure is stacked or thrown loosely in heaps and left exposed to the weather. Unless frequently turned over and kept moistened with water or urine the manure heap will gradually allow the best part of its fertilizing ingredients, namely, the ammonia gas, to vanish into the air, a misfortune readily recognized by the smell given off. Or the heavy rains wash out all the soluble salts into the drains, where they are lost. The result often is that the "life" of the manure has departed, and nothing is left but the dead carcass. To avoid these calamities it is therefore best to have the manure under cover if possible, and placed on concrete bottoms, so that any liquid oozing out may be afterwards collected and thrown over the heap. If a piece of moistened *red* litmus paper be placed near a steaming manure heap it will turn *blue*; and a glass rod dipped in

spirits of salts (hydrochloric acid) will be covered with a white crust of sal ammoniac, produced by the union of the acid with the escaping ammonia.

Manure should be well packed or trodden down, as it loses ammonia more readily if left in a loose condition, Wonderful chemical changes take place rapidly in the heap, and micro-organisms are at work reducing the organic material into a finer, less littery, and more fertilizing compost. In this way the manure heap loses considerably in bulk, and the farmer and gardener must take care not to let it remain too long before working it into his soil. It has been computed that 100 loads of fresh dung left exposed to the action of the weather loses nearly 27 loads in 81 days, 35½ loads in 254 days, 37½ loads in 384 days, and about 53 loads (over one-half) in 493 days.

Growers of flowers, ferns, palms, &c., use stable or farmyard manure in fairly large quantities, but not of course so largely as market gardeners and farmers; and many of them preserve all the ingredients of the manure by stacking it in layers with soil. Thus a bed is marked out, and perhaps a layer of soil 1 ft. thick is spread over it. On top of this a layer of manure 3 or 4 ft. thick is placed. Then another layer of soil, followed with a layer of manure, until the material is used up—the top layer always being soil. Arranged in this sandwich-like way, the layers of manure decay evenly, and at the same time fertilize the layers of soil. In due course the compost is chopped down with the spade, and is used in various proportions with other soil for any special crops. While it may not be always possible or convenient for market gardeners to store manure in this way, those who cultivate plants of any kind in pots will find it an excellent method of producing a rich and agreeable compost.

Value of Farmyard Manure.—Farmyard manure is a bulky manure, but in a good condition it is probably the best and safest of all manures, natural or artificial. Although 1 ton of it only contains from 9 to 15 lb. nitrogen, 4 to 9 lb. phosphates, 9 to 18 lb. potash, and 39 lb. carbonate of lime, its fertilizing value must not be judged from these quantities on the unit system applied to artificial manures like sulphate of ammonia or nitrate of soda. While it is in itself a complete manure, containing all the foods from the soil, water, and air, it possesses mechanical advantages superior to any other manure. Being bulky, when dug into the soil it pushes the clods asunder and allows fresh air and water to enter freely. By its decomposition or fermentation heat is generated, carbonic acid gas is given off, minerals and metals are rendered soluble in conjunction with lime, and millions of bacteria are brought into being to produce other foods in the soil. These important functions cannot be performed or brought about by any chemical manure by itself, and it would be courting disaster to use them exclusively on any soil.

The quantities of farmyard manure necessary to keep a soil in a fertile condition vary according to the soil and its nature. On loamy soil in a well-cultivated condition from 12 to 16 tons may be regarded as a fair dressing. In a heavy loam, or clayey soil as it is often called, from 16

to 24 tons to the acre would not be too much. And in light, sandy, or gravelly soils, which are notoriously hot and hungry, from 30 to 50 tons per acre would be hardly sufficient to obtain good results. It will thus be seen that although a light sandy soil may be had at a very low rent, this advantage will vanish completely when the expenses of manuring and cultivating are compared with those of loamy and clayey soils.

A Warning.—Although farmyard manure possesses the great virtues mentioned it must be used with care and intelligence. In some places, where large and cheap supplies are available, the soil is saturated with manure. The greater the quantity of manure incorporated with a soil the greater the necessity for plenty of fresh air to bring about decomposition, and ultimately humus. Now, if a soil has not been deeply dug or trenched, and it happens to be of a heavy nature, it is possible that the rains will not pass away readily. Then the manure begins to get sour, fresh air with its oxygen is driven out, carbonic acid gas develops too freely, and the beneficial bacteria are suffocated or annihilated by their enemies which come into being owing to the lack of fresh air. To avoid these troubles the soil should be well and deeply dug, and whenever extra large quantities of manure are used the soil should afterwards be dressed with lime or chalk, basic slag, or nitrolim, to keep it in a sweet condition.

Green Manuring.—This consists in growing a crop of some quick-growing plant, which when near maturity is to be ploughed in or dug into the soil, with the object of enriching it in humus or organic material and nitrogen. Sometimes the crop is fed to cattle, and the manure from the sheds is afterwards returned to the land. As one of the chief objects of green manuring is to supply nitrates to the soil, such leguminous plants as the Red, White, and Crimson Clovers, Peas, Vetches, Beans, Lupins, &c., are favoured for the purpose, because the bacterial nodules on their roots possess the power of fixing the free nitrogen from the air (see p. 127). Such non-leguminous crops as Mustard, Rape, Buckwheat, Borage, &c., are also grown as green manures because of their bulkiness and rapidity of growth, and the large amount of humus, &c., they return to the soil.

Whichever of these crops is grown the effect upon the soil is beneficial. The roots penetrate the soil and divide it into finer particles. Mineral and metallic foods are dissolved by the secretions from the roots, and being rendered soluble in water can be absorbed into the system of the crop. The soil becomes drier by the absorption and transpiration of moisture if it is inclined to be too wet; and eventually when the crop is ploughed in, or dug in completely, large quantities of humus become incorporated with the soil. As the green stems and leaves and roots decay in the dark a certain amount of heat is generated, carbonic acid gas is liberated and proceeds to dissolve the inorganic materials in the soil, and all the wonderful chemical changes due to the presence of humus take place in proper order to make the soil richer than it was before.

Many experiments have been carried out to prove the value of "green manuring", and an interesting paper on the subject will be found in the *Journal of the Board of Agriculture*, for June, 1897. The following figures show how a soil may be enriched in nitrogen and other foods when a green crop is incorporated with it:—

Name of Crop.	Dry Substance per Acre.	Fixed Nitrogen per Acre.	Equal to Nitrate of Soda.
	lb.	lb.	lb.
Lathyrus Clymenum ...	5100	154	1000
Peas	7140	198	1267
Mixed leguminous plants	5998	165	1028
Lupins, white	6273	162	1039
„ blue	7020	171	1081
„ yellow	5090	130	847

From this experiment it would appear that Peas are the best crop to use as a green manure. Not only is there a larger supply of dry substance (over 3 tons per acre), but nearly 200 lb. of nitrogen is fixed in the soil. This is equal to over ½ ton of nitrate of soda. Reckoning the value of nitrate of soda at £10 per ton, the pea crop yielded up nitrogen to the value of £5 per acre, in addition to the other foods supplied by the decaying stems, leaves, and roots. The Yellow Lupins supplied over 5000 lb. of dry matter, and 130 lb. of nitrogen to the acre, and is thus the poorest of the leguminous fertilizers. Notwithstanding this fact it appears that any of the green manures mentioned are capable of supplying more nitrogen to the soil than is needed by most crops. Hops require about 200 lb. of nitrogen per acre, and this quantity can be supplied in advance by a crop of Peas. But Potatoes require from 50 lb. to 120 lb. of nitrogen per acre, and leguminous crops can supply far larger quantities as shown. The value of leguminous crops as manure was well known to the ancients, and Virgil in his "Georgics" refers to them thus:—

> "At least where Vetches, Pulse, and Tares have stood,
> And stalks of Lupines grew (a stubborn wood),
> The ensuing season, in return, may bear
> The bearded product of the golden year".

Leaves as a "Green Crop".—The subject of green manuring may be carried further than is generally supposed. There is scarcely a crop grown, whether fruits, flowers, or vegetables, that cannot be utilized in part as a green manure. Even the weeds and herbage from the banks and waysides can be turned to good account as soil fertilizers, and if utilized will not only pay as a green manure but will also remove one of the chief nesting places for many garden pests.

Taking cultivated crops, the leaves of many of them drop to the ground in autumn and when decayed form an excellent vegetable mould or leaf

soil, the value of which is well known to all gardeners who cultivate pot plants of any description. But the leaves and stems of such crops as Potatoes, Carrots, Parsnips, Turnips, Beet, Mangel, Peas, Beans, Jerusalem Artichokes, and the stems of many Cabbage crops, &c., are often available as vegetable refuse, and may be utilized to improve the soil. The quantities of leaves and stems vary according to the different crops, but the following is a fairly approximate estimate per acre of some. Beet, 15 tons; Cabbage crops, 7 tons; Jerusalem Artichokes, 13 tons; Turnips, 12 tons; Potatoes, 6 tons; Parsnips, 10 tons; Apples, Pears, and Plums, 4 tons.

Vegetable refuse of this description, as well as the clippings of hedges, the dead stems and leaves from flower borders, &c., makes an excellent fertilizing material for the soil. It may be utilized in a green or raw state whenever the ground is being trenched, or in a decomposed state as a compost when digging or ploughing. Many market gardeners and farmers are well aware of the value of this material and take advantage of it.

The only danger to be apprehended is in the case of Potato stalks and clubrooted Cabbages. These contain terrible fungoid diseases, and it is generally safer to have them burned than dug into the soil. Although burning will drive off all the organic foods, the ashes left behind will contain valuable fertilizing salts that may be dug in afterwards.

Roots as a Manure.—Besides the overground stems and leaves of crops, one must not forget the roots. Although many crops are said to be cleared off the ground, the fact remains that a very large quantity of fibrous roots of all crops are left behind in the soil; and the more rudely the plants are taken up the larger the quantity of roots left behind. This may be easily seen by pulling up a cabbage or a lettuce by hand, and comparing the roots attached with those on similar plants that have been carefully lifted with a fork. As the roots decay they become humus and have all the fertilizing value of that organic material. It has been estimated that in an acre of grass land at Rothamsted there were over 4½ tons (10,400 lb.) of roots in the soil at 9 in. deep; and these roots contained 78 lb. of nitrogen to the acre.

It will thus be seen that, even if stable manure and artificial fertilizers are excluded altogether, very large supplies of plant foods may still be secured from the waste leaves, stems, and roots of the crops themselves. It is therefore wise to take a leaf out of the book of the Continental, as well as the Chinese and Japanese cultivators, and avoid wasting the vegetable remains of any crop. If they are burned or thrown away, it is equivalent to wasting valuable supplies of nitrates, potash, phosphoric acid, lime, sulphur, soda, magnesia, and other plant foods, for which high prices will have to be paid.

Guano.—This is a valuable manure, consisting chiefly of the dried excrements and waste of sea birds, which have accumulated for centuries on the coasts and rainless districts of Chili and Peru. The famous traveller Humboldt first brought samples of guano to Europe in 1804,

but it was not till 1840 that the first cargo reached Britain. Five years later nearly 300,000 tons were imported, and enormous quantities arrived annually, until soon after 1870 the supplies began to get exhausted. The Peruvian guanos are now completely worked out, and supplies have to be obtained from other sources, such as the coasts of Bolivia, Colombia, and Patagonia, Australia, South-west Africa, and certain islands in the Pacific. The importations now are small in comparison with those of earlier times. In 1901 only 13,000 tons were imported, and in 1907, 31,278 tons of all kinds of guano. The original Peruvian guanos were very rich in plant foods, containing 14 to 16 per cent of nitrogen, 12 to 14 per cent of phosphoric acid, and 2 to 3 per cent of potash. They were thus "complete" fertilizers. Modern guanos, however, seldom contain more than 10 per cent of nitrogen, and may contain as little as 2½ per cent. Purchasers should always insist on obtaining a warranty when buying guano, and samples should be analysed from time to time to test the manurial value.

"Guanos are commonly divided into nitrogenous and phosphatic. Nitrogenous guanos are those which contain a considerable percentage of nitrogen, generally over 4 per cent. They may also contain a large percentage of phosphate. A recent sample, for instance, contained 6·3 per cent of nitrogen and 32 per cent of phosphate. Phosphatic guanos, on the other hand, contain little nitrogen, generally from 1 to 3 per cent, but they should contain a considerable percentage of phosphate. Usually the phosphate is from 30 to 50 per cent, but samples containing as much as 70 per cent are sometimes on the market" (*The Standard Cyclopedia of Modern Agriculture*).

Fish Guano.—Soon after 1870, when the supply of Peruvian guano began to fail, it was thought that fish refuse might be utilized for the production of guano—especially as the latter manure came from birds that fed largely on fish. Although the methods of manufacture were at first very crude, and a good deal of oil was incorporated with the manure, great improvements have been effected in late years. Fish guano is chiefly valuable as a manure for its nitrogen and phosphates, the quantities of which vary according to the kind of fish. The supply of nitrogen will be larger in fish having plenty of flesh and little bone, while the phosphates will be greater in fish having much bone and little flesh. There is also a small quantity of potash and lime. The nitrogenous value varies from 7 to 16 per cent, according to the kind of fish and the process of manufacture. The phosphates vary from 3 to 20 per cent. What is known as "white fish" guano is made from the heads, bones, and waste of haddocks, cod, ling, and other non-oily fish, and is superior to the guano obtained from herrings.

Seaweed.—Various kinds of seaweed have long been used as manure when obtainable in sufficient quantities round the coasts. The commonest kinds are species of Laminaria and Fucus, the latter genus supplying two well-known species met with almost everywhere, namely, *F. vesiculosus*

and *F. nodosus.* Seaweed is variously known as wrack, bladderwrack, black wrack, and black tang in different parts. During the summer months, after the tide has receded, the seaweed is gathered and laid out to dry along the shores. It is turned over a few times, as if it were hay, and when sufficiently dry is stacked in conical heaps for autumn and winter use. During the winter seaweed cannot be dried and stacked in this way, as it melts away into an oily liquid. It is therefore applied direct to the soil when collected at this season. The value of seaweed is due to the amount of potash it contains—from 30 to 40 lb. in a ton. It also contains about 10 lb. of nitrogen and 10 lb. of phosphoric acid, as well as 11 to 18 lb. of lime to the ton. It is therefore a "complete" manure, but is not so valuable as farmyard manure. For Potatoes, Peas, and Beans it is excellent in light soils, and a good dressing would be from 12 to 20 tons per acre.

Soot.—This is principally composed of carbon, and is not only valuable as a manure, but also as a preventive against attacks of slugs, snails, caterpillars, &c. One ton of soot contains about 90 lb. nitrogen, 25 lb. phosphates, 25 lb. potash, and 200 lb. carbonate of lime. It is therefore an excellent all-round manure, and after it has been exposed to the air for six or eight weeks may be safely used for almost any vegetable or flower crop in the open air. From 30 to 50 bus. per acre is a fair dressing. Soot is highly valued as the basis of a liquid manure by gardeners who grow large numbers of plants in pots. About 1 pk. to 30 gal. of water will yield a useful liquid manure. It is better to put the soot into a bag and sink it in a tub of water, as the loose soot does not mix freely with the water. Owing to its chemical composition it is a much better and safer liquid manure than sulphate of ammonia or nitrate of soda.

Blood Manures.—Blood may be regarded as a complete fertilizer, as it contains not only nitrogen (from 2½ to 5 per cent in a fresh state, and from 6 to 14 per cent in a dried state) but is also rich in all other plant foods, as may be seen by the following analysis of the ash:—

	Per cent.
Sodium phosphate	16·77
Calcium and magnesium phosphates	4·19
Oxide and phosphate of iron	8·28
Sodium chloride (common salt)	59·34
Potassium chloride	6·12
Calcium chloride	3·85
Calcium sulphate (gypsum)	1·45
	100·00

It will be observed that common salt constitutes more than half the weight of blood ash. When fresh blood can be obtained from slaughter houses it is best mixed with large quantities of soil and then allowed to "mature" in a heap until wanted for use. *Dried blood* is a more concentrated source of nitrogen than fresh blood, as water has been eliminated. It is a good

fertilizer for all well-worked soils, and may be regarded as specially valuable for Potatoes, Cabbage crops, Vines, and fruit.

Night Soil and Poudrette.—Human excreta are rich in fertilizing substances, and their value as manures was more highly appreciated before the general adoption of the water closet and sewage systems. Even to-day the Chinese and Japanese gardeners, who achieve such marvellous results, have the highest respect for night soil as a fertilizer. On the Continent also it is valued as a manure; and under the pretty name of "poudrette" it is found mixed with gypsum, ashes, earth, peat, sawdust, &c., to mask the smell. Some market growers of flowers now use night soil for purposes of liquid manure.

Closely associated with night soil is the "native guano" obtained from the precipitated solids in sewage beds. It is mixed with various things, such as alum, charcoal, &c., and is sold in a dried state. A ton of it contains from 20 to 40 lb. of nitrogen, 60 to 120 lb. phosphate of lime, and about 50 to 100 lb. of alkalis of potash, soda, and magnesia. If too many poisonous chemicals have not been used at the sewage works, native guano is worth using as a topdressing at the rate of ½ ton to the acre.

Rape Cake and Rape Dust.—Rape cake is largely used by some agriculturists not only as a manure but also as a wireworm catcher. Rape cake contains a certain amount of oil, but of late years this has been almost entirely extracted, and the cake is made up into the form of meal. As a manure it is chiefly valuable for its nitrogen, 1 ton containing about 100 lb. There are also smaller quantities of phosphates, potash, and lime present, thus making rape cake and rape dust a complete if not very rich manure. It is useful as a topdressing at the rate of ½ ton to the acre; or it may be dug or hoed in.

Malt Dust or Kiln Dust.—This is obtained from malt houses and consists of the dried rootlets and shoots that have been screened from the kilned malt. Malt dust is a very useful organic manure, and may be regarded as a complete fertilizer. It is excellent as a topdressing at the rate of 30 or 40 bus. to the acre, particularly during hot, dry summers. The ash is rich in phosphates (25 per cent) and in potash (30 per cent), but contains little lime (3 per cent). The market price of malt dust varies from 35*s*. to 60*s*. per ton.

Wool and Shoddy.—Pieces of woollen cloth and shredded portions called shoddy are valuable organic manures, being chiefly valued for their nitrogen. This varies from 2 to 13 per cent, according to the purity of the wool from which the shoddy is obtained. As it liberates its nitrogen slowly, shoddy is regarded as a good manure for Hops, Vines, Roses, &c. Besides wool and shoddy all waste cloth refuse might be converted into a manure. It should be placed in layers and covered with soil, and when thoroughly decayed may be spread over the soil as a topdressing. The soil prevents the escape of any ammonia gas generated in the process of decomposition.

Hair, Feathers, Skin, Leather Waste, Greaves may be associated

with wool waste and shoddy as manures. They all contain appreciable quantities of nitrogen, and when thoroughly decomposed and matured by mixing with layers of soil, they constitute valuable organic additions to the soil.

§ 4. NITROGENOUS MANURES

Nitrogenous manures are chiefly valuable because they give a luxuriance and brilliancy of colour to the foliage of plants, thus enabling them under healthy conditions to absorb sufficient supplies of carbonic acid gas from the atmosphere during the daytime. The practical gardener may therefore by a mere glance at his plants be able to say whether his plants are lacking in nitrogenous food or not. When the leaves are luscious and deep green, and the shoots are gross and sappy, it is a sure sign that there is an abundance of nitrates in the soil. Such rank growth can only be produced by their presence. It would therefore be a mistake to add nitrogenous manures to such a soil. To check the rankness of growth, however, it would be wise to add phosphates, potash, or lime, and thus induce the formation of flowers and fruits instead of wood.

Amongst natural substances which supply nitrates to the soil are farmyard and stable manure, leaves, the dung of such animals as the horse, cow, pig, sheep, poultry, rabbit, and all refuse from them, such as wool, shoddy, horn, hair, feathers, skin, leather, meat meal, dried blood. To these may be added fish manure, oilcake manure, night soil, and poudrette.

Indeed these materials not only supply nitrogen, but also certain quantities of potash, phosphoric acid, and lime, as well as other foods. They may therefore be looked upon as complete fertilizers.

Amongst artificial manures supplying nitrogen are nitrate of soda, sulphate of ammonia, nitrate of potash, nitrate of lime, nitrogen, and guano.

When the natural manures, which are all of animal origin, are incorporated with the soil, and are in a thoroughly decayed condition, they possess all the advantages of humus, and are safe and reliable. They keep the temperature equable, retain sufficient moisture, bring bacteria into being, dissolve mineral matters, and gradually yield up their foods to the roots of the plants.

Nitrate of Lime.—This is a new nitrogenous fertilizer produced from the oxygen and nitrogen of the atmosphere by an electrical process. The commercial product is a hard crystalline substance which contains about 13 per cent of nitrogen. It is very soluble in water and has the disadvantage of being very deliquescent, owing to its affinity for moisture in the air. It must therefore be kept in a very dry place, and it is best used as a topdressing to growing crops in the same way as nitrate of soda.

Nitrate of Soda or Chili Saltpetre.—This is one of the best-known artificials, and enormous quantities are sold every year. It is found in layers of varying thickness in parts of Chili, whence 1,733,540 tons were

exported in 1908. The Continent absorbed 1,272,000 tons, the United States 308,000 tons, and the United Kingdom 105,000 tons, about one-half the supply being used for agricultural and horticultural purposes.

Commercial nitrate of soda contains from 95 to 96 per cent of actual nitrate of soda, the remaining 4 to 5 per cent consisting of moisture, salt, soda, magnesium sulphate, &c. The best samples with 95-per-cent purity contain about 15·6 per cent of nitrogen, this being equivalent to 19 per cent of ammonia.

Nitrate of soda is a very quick-acting manure—that is, it yields up its nitrogen soon after application and especially after a shower of rain. It should therefore only be applied to soil which is carrying a crop in full growth, and which shows by the colour of its foliage that a dressing would be beneficial. As growth is most rapid in spring and summer, these are the best seasons for applying nitrate of soda. As an autumn or winter dressing it would be practically wasted. The quantity given will vary from 1 cwt. to 2 cwt. per acre, or, roughly, ¾ lb. to 1½ lb. to every square rod or pole of ground. As a stimulant in conjunction with organic manures already in the soil, nitrate of soda is excellent for Cabbage crops, including Turnips and Kohl Rabi, as well as for Beet, Spinach, &c. It is only rarely necessary to apply it to leguminous crops like Peas and Beans, as these are capable of securing their own supplies of nitrogen from the atmosphere. Perhaps the best way to use nitrate of soda is as a topdressing, afterwards working it into the soil with the hoe; or for pot plants by dissolving about 1 oz. in 1 gal. of water. If used dry, a mere pinch—as much as will cover a threepenny piece—is quite sufficient for plants in 5-in. pots.

Nitrate of soda may be used with basic slag, but should never be mixed with sulphate of ammonia or kainit; and it can be only safely mixed in small quantities with superphosphate of lime, owing to the danger of decomposition.

Nitrate of Potash.—This is popularly known as "saltpetre" or "nitre". Owing to its high price it is very little used by farmers and gardeners. It is not only rich in nitrogen, but also in potash, and should therefore be regarded more as a potassic manure. When of 85-per-cent purity it contains 14 per cent of nitrogen and 40 per cent of potash.

Sulphate of Ammonia.—This resembles nitrate of soda somewhat in appearance but is rather coarser in the crystals. It is a compound of ammonia and sulphuric acid, and is obtained from the ammonia liquor of gasworks, ironworks, &c. In a pure state it contains 25·8 per cent of ammonia, equal to 21·2 per cent of nitrogen. A pinch of unadulterated sulphate of ammonia will vaporize completely on a red-hot surface. The commercial product, however, of about 95-per-cent purity contains 24·5 per cent of ammonia, equal to 20·2 per cent of nitrogen. It may be used in the same way as nitrate of soda, but is more lasting in its effects. It should not be mixed with nitrate of soda, basic slag, or with lime or chalk, as these would liberate the ammonia and cause it to be lost.

The production of sulphate of ammonia has increased from 42,000 tons

in 1872 to 289,000 tons in 1906, and more than one-half the quantity is obtained from gasworks.

Sulphate of ammonia is neither an acid nor an alkaline manure; it is a neutral substance, and when added to the soil causes a loss of calcareous or chalky food (see p. 161.)

Nitrolim or Calcium Cyanamide.—This manure has recently come into prominence as a nitrogenous fertilizer. It is obtained from calcium carbide, so much used for acetylene gas. When this is heated to 1000° C. the nitrogen from the atmosphere combines with it and forms about 60 per cent of calcium cyanamide. This contains 20 per cent of nitrogen, the remainder being 24 per cent quicklime, 10 per cent carbon, and 15 per cent of various mineral oxides. In appearance nitrolim resembles basic slag, being a dark-grey finely powdered substance. In action it is somewhat similar to sulphate of ammonia, and is much slower in its action than nitrate of soda.

§ 5. PHOSPHATIC MANURES

Phosphatic manures are derived from various sources, and are valuable because they induce the earlier production of flowers and fruits. They are mainly useful for the supply of phosphoric acid, which is an ingredient of every part of a plant, and exists in considerable quantities in some, such as the Cauliflower, the Radish, Peas, and Beans. There are fair supplies of phosphoric acid in the soil, as much as 2750 lb. to the acre being recorded at Rothamsted in a field that had not been manured for fifty years. As already stated, from 20 to 125 lb. of phosphoric acid per acre is a sufficient supply for most crops. These quantities may be liberated by deep cultivation and the addition of stable manure, and by the judicious application of some of the following "artificials", chiefly remarkable for their phosphates.

Bones.—The use of bones as a manure dates from the earliest times, and has become more extensive than ever. Between 45,000 and 60,000 tons of bones in various forms have been imported annually in recent years from the East Indies, the Argentine, Brazil, Morocco, Egypt, and the Continent. In addition to this it is computed that about 60,000 tons of bones are also available annually in the United Kingdom. This would bring the manurial consumption of bones up to about 100,000 tons per annum.

In a natural state bones are crushed into various sizes, and in the form of bone meal are very popular with gardeners. A ton of bone ash contains from 800 to 900 lb. of phosphates; while 1 ton of dissolved bones, and 1 ton of steamed bones contains from 300 to 600 lb. of phosphates. Bone flour is also a valuable phosphatic manure, containing over 300 lb. of phosphates in 1 ton, and also yielding up a small quantity of nitrogen. Dissolved bones also yield up even a larger supply of nitrogen.

Superphosphate.—This is one of the most popular phosphatic manures.

It is obtained by treating substances containing tricalcium phosphate with sulphuric acid. At first superphosphate was made from bone ash and bone black, but the great bulk is now obtained from natural minerals (phosphorites, coprolites, apatites). Many millions of tons are produced annually, about 800,000 tons being manufactured in the United Kingdom. Commercial samples contain from 25 to 40 per cent of soluble phosphates, but there is great variation. When buying, the *soluble* phosphates only should be taken into account, the *insoluble* phosphates not being highly valued.

When superphosphate is applied to the soil, the phosphates, being soluble in water, are well distributed amongst the soil particles by a shower of rain. Then a change takes place. The soluble phosphate reverts into an insoluble state owing to the carbonate of lime (or chalk) and the compounds of iron and alumina present in the soil. This change prevents the phosphates from being washed out of the soil too readily.

Superphosphate is an acid manure, and therefore tends to use up the available lime in the soil (see p. 161).

Basic Slag.—This is a by-product in the manufacture of Bessemer steel, and is also known as "basic cinder" and "Thomas's phosphate". It is a fine dark-grey powder, 80 per cent of the particles of which should pass through a sieve having 10,000 holes to the square inch. It is only since 1885 that basic slag has been used as a manure, having previously been discarded as a waste product. The estimated production for the whole world in 1885 was 150,000 tons, and in 1906 as much as 2,383,000 tons. Of this quantity Germany produces 1,510,000—more than one-half; the United Kingdom being second with 300,000 tons.

Basic slag is an alkaline manure, and usually contains from 30 to 40 per cent of phosphate of lime, which is equivalent to 9 to 18 per cent of phosphoric acid. The phosphate in basic slag is in combination with lime, and in good samples the greater part of the phosphate can be dissolved in a dilute solution of citric acid. As the value of basic slag depends largely upon its solubility in citric acid, purchasers should obtain a guarantee as to its citric solubility, as there are inferior brands of basic slag in existence. If 90 per cent or more is soluble, the sample is a good one.

Basic slag is a valuable manure for all soils except those of a chalky or limestone nature. It is particularly valuable where large quantities of stable manure have been applied, and where there is a tendency to acidity. For fruits, flowers, and vegetables of all kinds basic slag may be used at the rate of 2 cwt. to 4 cwt. per acre. There is a general impression that it should be used only during the *winter* months. In practice it will be found useful if applied to the soil about three months before the crops are likely to require it. It yields up its phosphates slowly, but in the meantime the lime is acting in conjunction with the humus in the soil and excites bacterial activity. When finally potting Chrysanthemums, Zonal Pelargoniums, Begonias, and a host of other plants, a sprinkling of

basic slag over the compost heap will produce excellent results in the way of early bloom, &c.

Wood Ashes, &c.—Besides bones, superphosphate, and basic slag, other manures are also valuable for the amount of phosphates they contain. Wood ashes, i.e. the burnt refuse from weeds and plants of all sorts, contain from 100 to 145 lb. of phosphates in every ton, and even a larger supply of potash—135 to 224 lb. in every ton.

Guanos—both Peruvian and fish—also contain large quantities of phosphates, Peruvian guano having from 350 to 400 lb. in every ton, and fish guano from 200 to 300 lb. Farmyard and stable manure, seaweed, sewage sludge, soot, night soil, pigeon, poultry, and all animal excreta contain supplies of phosphates as well as nitrates and potash.

Limphos.—This name has been given to a new fertilizer, said to contain 40 per cent of phosphates and 35 per cent of lime. It is probably a commercial name for a form of superphosphate, and is no doubt similar in action.

§ 6. POTASH MANURES

It must be a very poor soil indeed which does not contain large supplies of potash. This is locked up with other elements, but fair quantities may be liberated annually by cultivation and the application of organic manures. A fertile soil has been computed to contain about 30,000 lb. of potash to the acre at 9 in. deep, while a soil at Rothamsted which had not been manured for fifty years contained 6750 lb. of potash to the acre at 9 in. deep. The quantity of available potash needed for certain crops varies from 36 to 500 lb. per acre, as may be seen by reference to the figures on p. 144.

Before referring to special artificial potash manures it may be remarked that all organic manures, such as stable manure, the dung of all animals and birds, soot, seaweed, and wood ashes, contain supplies of potash, which are liberated when incorporated with the soil.

Amongst the special potash manures are the following:—

Kainit.—This is one of the most popular potash manures at present in use. It is a crude natural salt obtained from Germany, and varies in colour from creamy white to pale pink. Pure samples contain potassium equal to nearly 19 per cent of potash. The usual commercial article only contains about 12·4 per cent of potash. In bulk, commercial kainit contains about 35 per cent of common salt, about 30 per cent of magnesium salts (chiefly Epsom salts), and about 12·5 per cent of water of crystallization. The remainder—22·5 per cent—is almost entirely potassium salts. It will thus be seen that less than one-fourth the bulk consists of the important fertilizer potash.

As a manure, kainit has the disadvantage of having such a large percentage (35) of common salt, but with such crops as Mangels and Asparagus this is not a drawback, as those crops benefit by the addition of salt to the

soil. It would, however, be unwise to apply kainit to a soil carrying growing crops, as the salt and other impurities are likely to injure the tender rootlets.

The best time to apply kainit is a few weeks before the crop is to be sown or planted. The salt in it, being readily soluble, will be washed down into the soil out of reach of the roots, and the potash will be left behind evenly distributed amongst the soil particles. From 2 to 4 cwt. per acre is a fair dressing for kainit.

Muriate of Potash.—This is another name for a more or less impure chloride of potassium. It is manufactured from carnallite, which is found in enormous quantities in the German potash deposits. It contains from 70 to 98 per cent of pure potassium chloride, and its chief impurity is common salt, which may vary from a mere trace to 20 per cent. Small quantities of magnesium chloride and magnesium sulphate are also present. The standard commercial muriate of potash usually contains 80 per cent of pure potassium chloride, which is equivalent to 50·5 per cent of potash. One ton of "muriate" thus contains as much potash as 4 tons of kainit. In practice it may be used in the same way as kainit, but only one-fourth of the quantity is needed—about 56 to 112 lb. per acre.

Sulphate of Potash.—This is a whitish crystalline salt manufactured from natural deposits in the German potash mines. As a manure, the best samples contain 98 per cent of sulphate of potash, equal to over 52 per cent of pure potash. Inferior samples contain about 90 per cent of sulphate of potash, equal to 48 per cent of pure potash. The double sulphate of potash magnesia, which contains a good deal of magnesium sulphate, is often called sulphate of potash, but it is inferior in potassic value. It contains about 50 per cent of sulphate of potash, equal to 27 per cent of pure potash.

Sulphate of potash has gained a great name as a potato manure. It is considered to produce tubers of better quality, but this would depend largely upon the character of the soil.

§ 7. CALCAREOUS MANURES

These are of a most important nature, and consist of lime in some form, such as quicklime, slaked lime, chalk, marl, gas lime, and lime shells. Lime is not only an essential plant food (see p. 108), but it plays an important part in the generation and activity of bacteria in the soil, and must be present to ensure fertility. Some soils are naturally of a calcareous nature, while others may be deficient. In a fertile soil it has been estimated that there are about 120,000 lb. of lime to the acre, but the quantity is very much less in others. In the Broadbalk Field at Rothamsted, which had not been manured for fifty years, as much as 62,250 lb. of lime is given for an acre of ground.

Since the advent of so many chemical manures the ancient practice

of "liming" the soil has largely gone out of fashion. Market gardeners and farmers, however, appear to be again waking up to the importance of lime, not only as a cheap and excellent manure, but also as a powerful check to "clubroot" in Cabbage crops, to "eelworm" in Cucumbers and Tomatoes and other crops, and by keeping many other pests at bay.

The old saying that—

> "Lime and lime without manure
> Makes both farm and farmer poor",

is perfectly true, and it illustrates the wisdom of our forefathers. Owing to chemical actions set up in the soil by the presence of lime, organic matter like stable manure is rapidly converted into such a state that its nitrates, potash, phosphoric acid, &c., are soon liberated and absorbed. Consequently, unless manure is added regularly to the soil, it would soon be brought into an impoverished state by the continual application of lime alone.

In a state of nature lime does not occur in a free state. It is usually combined with carbonic acid, and in many parts is found in abundance as carbonate of lime—the commonest forms of which are limestone and chalk. Pure carbonate of lime is composed of 53·6 per cent of lime and 43·7 per cent of carbonic acid. When burnt in a kiln the carbonic acid gas is driven off into the atmosphere, and the residue—quicklime—is formed. This quicklime absorbs water greedily, and in coming in contact with it becomes "slaked". This is then called hydrate of lime, or, more properly, slaked lime. If left exposed to the air the slaked lime gradually loses its water, and absorbs carbonic acid gas instead. It thus becomes carbonate of lime once more.

In wet, heavy, clayey soils the application of "quicklime" or caustic lime to the surface is of the utmost benefit after the soil has been turned up with the spade, fork, or plough. The quicklime readily absorbs the surrounding moisture, generates great heat, and brings the soil into a drier and better condition for working. For heavy land there is nothing better than a good dressing of quicklime to bring it into a state of cultivation. From 30 to 200 bus. per acre is applied according to circumstances.

Chalk, or carbonate of lime, is also an excellent dressing for most farms and gardens that receive liberal dressings of manure. The latter is apt to generate acidity if the soil has not been deeply dug or trenched, and this acidity in turn is apt to produce clubbing of Cabbage crops, eelworm, and other plant diseases, owing to the lack of oxygen in the soil. Lime in any form helps to check this state of affairs.

Marl, which is a mixture of clay and chalk in varying proportions, is a useful adjunct to light or gravelly soils, because it makes the particles more tenacious, and this enables the soil to hold manures better. There are several kinds of marl, such as clay marl, sandy marl, chalk marl, slaty or stony marl, shell marl, and peaty marl—all containing a certain quantity of calcareous matter.

A SHOWER BOUQUET

A BASKET OF FLOWERS

FLORAL ART

Gas Lime obtained from the gasworks is often used for garden purposes. In a fresh state it contains many compounds fatal or poisonous to plant life; but in this state it is a valuable dressing for soil infested with clubroot (*Plasmodiophora*). It must not, however, be applied in a fresh state to land already carrying a crop. After exposure to the weather for about three months gas lime loses its poisonous properties and then becomes a very useful manure. In composition it may contain as much as 40 per cent of chalk (calcium carbonate) and 15 per cent of slaked lime, but the amount of these varies considerably. About 5 tons to the acre is a fair dressing.

Other lime manures are shells of various descriptions when ground and obtainable in sufficient quantity. They are valuable for their carbonate of lime and a certain amount of organic matter.

Since basic slag (see p. 157) has become prominent it is often used instead of lime, and an excellent substitute it is, as it contains large quantities of lime in a mild and useful form.

It has been found by experiment at Rothamsted that the application of sulphate of ammonia to the soil causes a loss of carbonate of lime (chalk), and growers would do well to bear this fact in mind. About 800 lb. of lime per annum is naturally dissipated from the top 9 in. of the soil by the action of the weather and cultivation, but the application of 400 lb. of ammonium salts raised the loss to 1045 lb. The loss of lime was still further increased to 1429 lb. per acre by the application of 400 lb. of ammonium salts and superphosphate. It is therefore a simple matter to rob a soil of lime simply by the careless or injudicious application of sulphate of ammonia, superphosphate, and other manures.

Gypsum (Calcium Sulphate).—This is well known as the source of plaster of Paris. As a manure it is rarely used by itself, but it is largely applied in the form of superphosphate. It is thought that the presence of gypsum in the soil not only increases the solubility of the potash, but also prevents the loss of nitrogen (in the form of ammonia) from stable manure. Some authorities doubt this; but in any case gypsum would scarcely pay for special application. It is favoured for light sandy or gravelly soils, from 2 to 3 cwt. per acre being considered a reasonable dressing.

§ 8. MISCELLANEOUS MANURES

There are few substances beyond those already mentioned used as manures, simply because there is very little to be obtained from them, or because the foods they yield are generally present in superabundance in the soil.

Magnesium Salts are sometimes applied as a potato manure, as magnesium carbonate or magnesium sulphate (otherwise Epsom salts). Magnesium occurs in the ash of all plants (see Tables at p. 109), and is returned to the soil in farmyard and other natural manures.

Iron is also one of the essentials of plant life, but there are usually large available supplies in the soil. Without a trace of iron it would be impossible for the chlorophyll or green colouring matter of leaves to develop, no matter how perfect other conditions might be. Recently sulphate of iron at the rate of 8 oz. to a square rod has been used where iron has been considered deficient owing to the yellowish colour of the leaves. When sickly looking yellowish-leaved plants will not respond to a complete fertilizer, or to a nitrogenous manure, the soil is then probably deficient in available iron. Very often, however, the yellowish appearance of leaves is due to sour and sodden soil, or to the absence of lime.

Salt, or **Chloride of Sodium,** is sometimes used as a special manure for Asparagus and Sea Kale and other plants. In weak doses it seems to be beneficial, and is said to liberate potash. From 1 to 2 lb. to the square rod may be used. Kainit, however, may be a safer manure to use in quantity.

§ 9. VALUATION OF MANURES

Chemical or artificial manures are valued chiefly by horticulturists and agriculturists for the amounts of nitrogen, potash, or phosphates they contain. The horticultural value, however, does not always correspond with the commercial or market value, as the latter may be affected by such questions as supply and demand, combinations, strikes, &c. The cultivator naturally wishes to obtain the best value for his money. Consequently, if he thinks he is paying too much for his nitrates, phosphates, or potash in a certain manure, he may cease to purchase it, and buy another that will supply his wants at a cheaper rate.

Artificial manures are now valued at "unit" prices for nitrates, phosphates, and potash, but these unit prices are subject to fluctuations.

Nitrogenous manures are valued at a unit price fixed for the percentage of nitrogen they contain; and nitrate of soda and sulphate of ammonia are taken as the standard nitrogenous manures. Thus, if a ton of nitrate of soda contains 15·5 units of nitrogen, and the price is £10 per ton, the value of the nitrogen will be $\frac{£10}{15·5}$, or about 12*s.* 10*d.* per unit. If 1 ton of sulphate of ammonia has 20 units of nitrogen, and is sold at £11 per ton, the unit price is $\frac{£11}{20}$, or 11*s.* It would therefore be cheaper to the grower to buy sulphate of ammonia at £11 per ton than to buy nitrate of soda at £10 per ton, as he would be obtaining better manurial value to the extent of 1*s.* 10*d.* per unit. Of late years the price of nitrogen has varied from 8*s.* 3*d.* to 12*s.* per unit.

For phosphatic manures superphosphate, basic slag, and ground Algerian phosphates are taken as standards. In a superphosphate containing 32 per

cent of soluble phosphate, costing £3 per ton, the cost per unit of phosphate would be $\frac{£3}{32}$ = 1*s.* 10½*d.* Basic slag at £2, 10*s.* per ton, and containing 40 per cent of phosphate, would represent a unit cost of $\frac{£2,\ 10s.}{40} = 1s.\ 3d.$ And ground Algerian phosphate at £2, 10*s.* per ton, but containing 60 per cent of phosphate, would show a unit value of $\frac{£2,\ 10s.}{60} = 10d.$

Insoluble phosphates, although not of such immediate value, are nevertheless reckoned in the price of manures, and vary from 1*s.* 4*d.* to 2*s.* 9*d.* per unit.

Potash manures are reckoned in the same way as nitrates and phosphates. Kainit, muriate of potash, and sulphate of potash may be taken as standard potash manures. Thus, in kainit containing 12½ per cent of potash, and costing £2, 5*s.* per ton, the phosphate would cost $\frac{£2,\ 5s.}{12\frac{1}{2}} = 3s.\ 7d.$ per unit nearly. Muriate of potash containing 50 per cent of potash at £9 per ton costs $\frac{£9}{50}$ = 3*s.* 7*d.* per unit. And sulphate of potash with 50 per cent of potash at £9, 10*s.* per ton would cost $\frac{£9,\ 10s.}{50}$ = 3*s.* 9¼*d.* per unit.

With such manures as nitrate of soda, sulphate of ammonia, basic slag, superphosphate, kainit, muriate of potash, and sulphate of potash, each valuable for a certain ingredient, it is easy enough to calculate the cost of nitrogen, phosphate, and potash per unit; but it is not so easy with manures containing more than one valuable ingredient. Nor must natural manures like stable or farmyard manure, dried blood, seaweed, &c., be valued on the same basis, because they possess other properties apart from their purely manurial value. If, however, the cultivator has a knowledge of the unit system of valuing artificial manures he will find it advantageous to buy sometimes one kind of nitrate, phosphate, or potash, and sometimes another, and use them as required.

If we take a complete fertilizer, that is, one containing nitrates, phosphates, and potash, at the unit values quoted above, we get an example as follows:—

		£	s.	d.
Nitrogen, 7 units at 11*s.*	=	3	17	0
Phosphate, soluble, 15 units at 1*s.* 10*d.*	=	1	7	6
,, insoluble, 7 units at 1*s.* 6*d.*	=	0	10	6
Potash, 5 units at 3*s.* 7*d.*	=	0	17	11
		6	12	11
Add 25 per cent for mixing, storing, bags, carriage, &c....		1	13	0
Total cost per ton		8	5	11

By obtaining a warranty with manures purchased, growers are thus able to arrive at a very fair estimate as to the value of their manures, if they price the percentage of nitrates, phosphates, and potash as given in the above examples.

Table showing the Approximate Quantity of Nitrates, Phosphates, Potash, and Lime contained in 1 Ton of Manure

Name of Manure.	Nitrogen in 1 Ton.	Phosphates in 1 Ton.	Potash in 1 Ton.	Lime in 1 Ton.
	lb.	lb.	lb.	lb.
Basic slag	—	300–400	—	1120
Blood, dried	280	200	130	190
Bone, ash	—	800–900	—	1120
„ dissolved... ...	50	300–350	—	—
„ flour	30	450–500	—	—
„ steamed	20–30	560–600	—	170
Chicken manure ...	43	39	19	58
Coprolites, Cambridge...	—	560	—	—
Coal ashes	—	15–20	56	—
Duck manure	27	31	13	23
Earth-closet manure ...	6–12	10	9–15	—
Farmyard manure ...	9–15	4–9	9–18	39
Geese manure	15	12	21	13
Guano, Peruvian ...	186	350–400	67	270
„ fish	160–200	200–300	—	110–180
Gypsum	—	—	—	500
Horn dust	260	—	—	—
Kainit	—	—	302	—
Leather waste	67–168	—	—	—
Marl	—	—	—	200–600
Meat meal	260	—	—	—
Malt dust (ash) ...	—	560	670	67
Muriate of potash ...	—	—	1120	—
Nitrate of lime	290	—	—	—
Nitrate of potash ...	313	—	1030	—
Nitrate of soda... ...	358	—	—	—
Nitrolim (calcium cyanamide) ...	450	—	—	530
Pigeon manure... ...	40–70	48	25	44
Rape cake	100	40	33	25
Seaweed	10	10	30–40	11–18
Sewage sludge	15–40	60–120	50–100	—
Soot	90	25	25	200
Shoddy and wool waste	44–260	—	—	—
Sulphate of ammonia ...	450	—	—	—
Sulphate of potash ...	—	—	900–1200	—
Superphosphate ...	—	270–290	—	—
Wood ashes	—	130–145	135–224	970

§ 10. MIXING MANURES

The grower who wishes to save money by purchasing only the manures he requires should also make himself acquainted with the different chemical effects of one manure upon another; otherwise it may happen that what is saved in one direction may be lost in another. If certain manures are mixed with others, the fertilizing value may be either neutralized or lost

altogether, owing to chemical changes taking place. The following hints as to the manures that may or may not be mixed with each other may be useful:—

Farmyard or *stable manure* should not be mixed with *lime*, because the lime drives off the ammonia gas into the air and thus causes it to be lost.

Nitrate of soda should not be mixed (except in small quantities) with *superphosphate*, as the sulphuric acid in the latter sets free nitric acid in the form of poisonous fumes, and the nitrogen is lost.

Sulphate of ammonia should not be mixed with *basic slag* or *nitrolim*, because the free lime in these manures would drive off the ammonia gas, and, if in an enclosed place, is so overpowering as to be dangerous.

The following mixtures may be made with safety:—

Sulphate of ammonia with superphosphate, dissolved bones, fish guano, and potash salts.

Nitrate of soda with basic slag, nitrolim, meat meal, kainit.

Kainit or *muriate of potash* may be mixed with superphosphate, although a little hydrochloric acid may be given off in fumes. [J. W.]

SECTION VI

Insect Pests

Within the past fifteen or twenty years commercial gardeners have taken a much keener interest in the various diseases and pests that prey upon their crops than their predecessors did. During that period great changes have taken place in cultural conditions, and all crops are now grown not only in larger quantities and on a more extensive scale, but in many cases under what may be called an "express" or "intensive" system. Every grower wishes to be first in the market, so as to secure the highest price; and this very craze to be first with everything has brought about insensibly and gradually changes in the constitution in the various kinds of plants grown for market purposes. At one period of the year they are forced or rushed into growth in great heat; at another they are retarded or kept in check in a freezing atmosphere; while in other cases, where neither forcing nor retarding is employed, some crops are so drenched with chemical manures that it is not at all surprising that some of them become so soft and tender in tissue as to fall an easy prey to fungoid diseases and to insect attack.

No crop is now immune from attack, and this knowledge keeps the commercial gardener constantly in a state of fear and apprehension. To add to his troubles, some diseases, notably the American Gooseberry Mildew, have been scheduled by the Board of Agriculture and Fisheries, and a grower having any bushes affected with this disease is liable to heavy penalties unless he reports the same. In some cases indeed, where the orders of the Board of Agriculture have been treated lightly, some market gardeners have been fined as much as £50.

Attacked by insect enemies and fungoid diseases on all sides, the market grower has called in the aid of the entomologist on the one hand and the chemist on the other, and has spent much money in experimenting with various remedies that have been recommended either to check his enemies or get rid of them altogether. The entomologist has assumed a prominent position in describing the habits and marriage customs of the various insects that are a plague to the gardener. And the mycologist or fungologist tells of the wonders he has discovered through the microscopic lens about the various fungi that make themselves unwelcomely at home on the roots, stems, leaves, flowers, and fruits of various crops.

With the aid of the mycologist, the entomologist, and the chemist, telling him what to do under every conceivable method of attack, the commercial gardener ought to be pretty well safeguarded by now, and the war he has been carrying on for years on insect and fungoid diseases ought to have decimated the ranks of his foes over and over again. But, alas! it is not so. The various injurious insect pests and fungi appear to be, if anything, in greater force than ever, and they infest our crops with as great persistence as in former years.

Enormous sums of money are spent annually in emulsions, mixtures, insecticides, fungicides, and poisonous nostrums of all sorts, in addition to grease bands, smudging materials, &c.; and the trade in these remedies seems to be getting larger instead of smaller. One would imagine that, if the various anti-pest remedies on the market possessed any efficacy at all, there should be very few insects left, and the trade in the remedies would naturally contract instead of expand. One must, of course, recognize that commercial growers are taking a keener interest in the diseases afflicting their crops than they used to, and this would account in a measure for the vast quantities of insecticides and fungicides that have been used of late years. The hard fact, however, remains, that there seems to be no diminution in either the numbers or attacks of the grower's persistent foes; and this indicates the impotency rather than the destructive power of the remedies.

While not wishing to minimize the value of the various insecticides and fungicides on the market, the writer is of the opinion that they are not always used to the best advantage and at times when they would be most likely to perform the work expected from them. Owing to the different natures and periods of destruction of the various insect pests and diseases, it is essential that different remedies must be adopted at the times when they are likely to prove effective.

Taking the insect pests first, they may be roughly divided into (1) pests under glass, and (2) pests in the open air.

Greenhouse Pests.—The insect pests that invade greenhouses are perhaps as difficult to eradicate as any. There are so many chinks and crevices in walls and floors for them to breed in, and they are so difficult to reach that it is not to be wondered at that they escape the effects of washes, vaporizers, and fumigators. While it is probably true that thousands of insects in an active state must succumb to the fumes and washes, on the other hand there must be thousands at the same time in a dormant stage that are not affected in the slightest degree, being protected by a covering that seems to be impervious to everything except fire. In due course such pests come forth, after the danger is past, and play havoc with the various crops, much to the surprise of the gardener, who thought he had disposed of them.

The practical question is: How best are these enemies to be destroyed? Certainly more drastic measures must be employed than those at present in force. If the pests nest in the soil of a greenhouse, the gardener cannot

expect any assistance from birds of the air to lessen their numbers, as a bird in a plant house is literally a *rara avis*, and is too frightened and flustered to search for the grubs or eggs of obnoxious insects. The grower of crops under glass must therefore rely upon other remedies. Besides using solutions made from nicotine, quassia chips, soft soap, arsenic, &c., on the plants themselves as preventives, the grower would be wise to cleanse his houses thoroughly after they have been cleared of the crops. The walls should be covered with hot limewash, and the woodwork should be painted at least once a year, but more frequently if possible; and if some paraffin and cement be churned up in the limewash, a thin covering will be applied to the walls that will seal up effectually the eggs of any pests that may be hidden in the crevices. In addition to this, sulphur or brimstone should always be burnt in an empty house before a fresh crop of plants is brought in. A strong sulphur vapour is not only fatal to insect pests but also to fungoid diseases. By this means such stove and greenhouse pests as scale, mealy-bug, red spider, thrips, slugs, snails, wood-lice, ants, &c., may be reduced almost to vanishing point. The keynote to immunity from pests in the greenhouse is cleanliness, not only of the structures themselves, but also in the methods of cultivation. A certain expense will be incurred, but it is better to spend it in this way than in trying to secure freedom from attack by artificial means.

Fumigating.—Besides keeping the walls and woodwork of glasshouses clean with limewash, paint, &c., it is more or less essential at times to fill the atmosphere with fumes that are deadly to pests that may be actually feeding upon the crops, or are likely to become a nuisance in that way. In former days the only method of cleansing a glass structure was by applying tobacco smoke in some way or another. If the genuine tobacco could not be afforded, rags and paper steeped in tobacco juice were utilized as substitutes. The tobacco, rags, or paper were placed in flower pots, or old saucepans, buckets, &c., with holes in them, on a few live coals in the bottom. The fumigating mixture was damped, but not sodden, with water, to prevent the flaring of the material, which would have been injurious to the plants in that state. By means of bellows the fire was kept alight, and as the moistened tobacco, paper, or rags were consumed, dense volumes of smoke filled the atmosphere, and while it destroyed the pests, if sufficiently powerful, also upset the operator in many instances. Great improvements have taken place in fumigating greenhouses of late years, and fumigating cones of various descriptions are now in use that will fill the house with fumes after being lighted, and will not necessitate the close attention of the gardener.

Vaporizing.—Nicotine in some concentrated form has always formed the staple fumigating material. It is now to be had concentrated in cake or liquid form, and, although apparently expensive, is really very effective. The cakes or liquid is placed in a shallow metal dish seated on a metal stand. A small methylated-spirit lamp is placed beneath, and when lighted dissolves the cakes or liquid into fumes that are diffused throughout the

houses. These fumes are fatal to insect pests of all kinds, and if properly applied are harmless to almost every plant. It is not wise, however, for the gardeners to remain long after the lamps are lighted.

Cyaniding.—Of recent years other methods of vaporizing have been introduced, the best known perhaps being that known as the cyanide process, in which hydrocyanic acid gas is diffused to kill mealy-bug, scale insects, and others. This gas is generated by mixing potassium or sodium cyanide, sulphuric acid, and water in various proportions. For Vines in leaf, and other plants, it is recommended that not more than $\frac{2}{3}$ oz. of potassium cyanide, or $\frac{1}{2}$ oz. of sodium cyanide, should be used to every

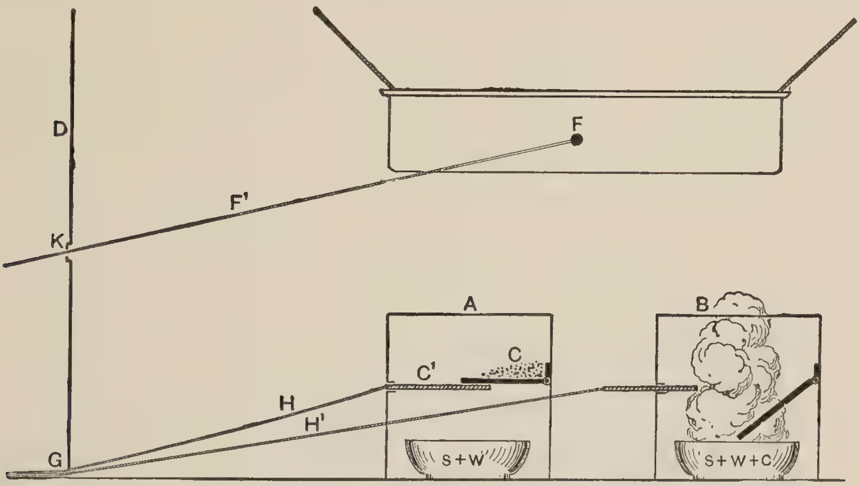


Fig. 91.—Diagram showing Method of Fumigating with Hydrocyanic Gas

D, Door of house. K, Keyhole. G, Space below door. F, Fan suspended from roof. F', String through K to move fan. A, Fumigating machine set for firing. C, Tray with cyanide. C', Movable support attached to string H passing under door. S+W, Bowl containing sulphuric acid and water. B, The same fired by pulling the string H'—bowl then containing all three ingredients, and gas generating.

100 cub. ft. of space. To every ounce of cyanide use 1 oz. of sulphuric acid and 4 oz. of water. The sulphuric acid and water are mixed slowly together, and then the cyanide is dropped into the liquid, and the poisonous gas, which is fatal to men and most animals, is rapidly generated and is best diffused by using a fan as shown in the diagram (fig. 91). Great care must therefore be exercised if these dangerous materials are used to vaporize planthouses. Even if the fumes are inhaled for a few seconds they may prove fatal. By using proper cyaniding apparatus, however, there is practically no danger in the hands of competent operators. The accompanying diagram will give one an excellent idea how a planthouse should be vaporized with hydrocyanic acid gas. Sodium cyanide is considered better to use than potassium cyanide, as it dissolves more readily and, taking weight for weight, liberates 30 per cent more gas.

Outdoor Pests.—These are far more numerous than those afflicting plants under glass. There is scarcely a fruit or vegetable, flower, tree,

or shrub that is not subject to attack from one or more pests. Unfortunately, few growers realize the mischief the various insects can do until some crop is almost destroyed by an epidemic. When the danger is discovered, then washes of all sorts and descriptions are tried, but they are often too late in their application to be of any value.

If one must use washes and sprays it is wiser to use them as preventives rather than as cures, and before there is any sign of the crop being attacked.

It is now well known that many leaf-eating and leaf-mining insects can be foiled by the early application of some good insecticide. Thus, aphides of all sorts, leaf-miners, caterpillars, and most soft-bodied pests are prevented from doing mischief if the plants are syringed or sprayed some time in advance of the usual period of attack. The various washes and insecticides are mentioned in connection with the crops they attack. As there is a right time and a wrong time for doing everything, the intelligent grower will naturally make himself acquainted with the period when certain insects are likely to commence their depredations, and spray in advance. It would evidently be useless to spray after the insects have eaten their fill and disappeared; applying insecticides under such conditions would be equivalent to locking the stable door after the horse had been stolen.

Seeking the Cause.—While the life-history and habits of the various insects that prey upon plants may possess a charm for the entomologist, the man who has to grow plants, flowers, fruits, and vegetables for a living is by no means enamoured of them. No matter how interesting and beautiful an insect may be in the various stages of its development, the cultivator looks upon it as an unmitigated nuisance, that must be suppressed at all costs. He regards nearly all insects as highway robbers, who not only take money out of his pocket for insecticides, but who add insult to injury by lowering or spoiling the market value of his produce, and preventing the proper development of his plants.

Now, apart from insecticides there is another and more natural way of combating these marauders. The cultivator should make himself acquainted with the habits of the various pests, so that he may discover their weakest and most vulnerable points. Having found these, then is the time to attack them vigorously, when they are neither able to resist nor escape; and although his efforts may not be crowned with complete success, he will have the satisfaction of knowing that he has reduced his tormentors to practically harmless proportions.

Life-history and Habits of Garden Pests.—Farmers, gardeners, and fruit-growers are indebted to the late Miss Ormerod and to the late John Curtis, and more recently to Professor F. V. Theobald, of Wye College, and Professor Walter Collinge, for the valuable information they have placed on record with regard to the habits of the various insect pests. Generally speaking, most of these have four different stages of existence:

1. The egg—a dormant stage.

2. The maggot, larva, grub or caterpillar—usually the most destructive stage.

3. The chrysalis or pupa—the dormant and non-destructive stage.

4. The perfect insect, which in many cases may possibly help to fertilize certain flowers at times.

The female insect is naturally more to be feared than the male, because in many species she is capable of depositing numerous eggs, from which in due course arise a devastating horde of hungry larvæ. There are thus two dormant stages in the life-history of an insect, namely, the egg stage and the chrysalis stage, and two active stages, viz. the larva and perfect insect. Some pests, however, notably the green fly or aphis, are not only egg-bearing but also viviparous, i.e. at certain seasons they bring forth young the females amongst which soon mature and bring forth families with amazing rapidity.

In the active stage it is sometimes difficult to catch and even to see some of the pests, as they assume many forms closely resembling in appearance and colour the leaves and shoots upon which they are feeding. The cultivator, however, with a keen eye will often detect the presence of insect pests when others may be oblivious to their presence. While washes and sprays applied at this stage will no doubt disable a large number of pests, many must escape destruction, being thus saved to do further mischief at some future time.

In the dormant stages of egg and chrysalis, however, the grower has the pests at his mercy, and then is the time to make war upon them. By destroying the eggs, future generations of caterpillars, &c., are suppressed, and by destroying the chrysalides the future perfect insects are prevented from giving rise to new families.

Methods of Prevention.—But how are these eggs and chrysalides to be destroyed? Entomologists tell us that the eggs of many insect pests are protected by a covering impervious to most, if not all, of the insecticides on the market. If that is so it would be waste of time and money to apply these washes. In a cold state possibly many washes may be harmless to the eggs of insect pests, but if applied hot or warm, in the form of fine spray, the liquid would probably soften the coat of the eggs and render them pervious to the destructive properties of the insecticide. The embryo larva would thus be destroyed. It may be stated that there is absolutely no danger in applying boiling-hot solutions to plants in the open air, provided they are applied in the form of a fine misty spray, and with as much force as possible. Even tender leaves of plants under glass will not be injured by hot washes applied in this way, because the minute globules of liquid are considerably reduced in temperature almost immediately they reach the surface of the plant. For outdoor work the only difficulty would be to maintain a large supply of liquid at a sufficiently high temperature to render it effective when applied to the eggs of insect pests.

Chrysalides.—In most cases these are to be found at rest in the soil. The chrysalis, or pupa as it is also called, is the stage of development

following that of the larva, maggot, or caterpillar, and preceding that of the perfect insect. When the larva has eaten and destroyed a certain amount of plant tissue, and has attained its full size, it then prepares to take a rest for a certain period. It exudes a secretion out of which a leathery protecting coat is formed, and it proceeds by a series of jerks to pull this coat over its body from the bottom upwards, much in the same way as if a man tried to pull a tight-fitting sack over himself from the feet upwards, until he could tie it over his head. While this process is going on, many larvæ hang by a silken cord from the bough of a tree, or shrub, or leaf, afterwards dropping down to the ground and burying themselves in the soil at certain depths. Other larvæ, however, spin cocoons in which they pupate and go to rest in the soil, in crevices of walls, &c.

The periods at which various insects go to rest in the soil vary according to their nature and habits, some being dormant either in spring, summer, autumn, or winter, while others are active and destructive. It is in this period of inactivity that the cultivator has the key to destroying the pests. There they are resting quietly in the soil, and so long as they are undisturbed there is every chance that they will come forth in the perfect insect stage to carry on mischief. Not only are the pests free from severe frosty weather by being buried in the soil, but what is of more importance is that they are also out of the reach and out of sight of the birds, whose beaks in most cases are either too short or too tender to pierce the soil covering the pupæ.

It is therefore to the treatment of the soil that the cultivator must pay more attention if he wishes to stop the mischief of these pests at the fountain head. So long as the soil is left uncultivated, so long are the pests quite safe from frost or birds. As soon, however, as the spade, fork, plough, or hoe is used to turn up the ground, then and not till then will the grower receive the assistance of nature's pest destroyers, the birds—thrushes, blackbirds, starlings, rooks, robins, sparrows, magpies, finches, owls, swallows, poultry, &c., that are ever on the watch to pick up any choice morsels of diet in the way of chrysalides or grubs that are brought within their reach. Birds are of the utmost assistance to the gardener; they render him valuable services free of charge, and are only too glad of having a free feed placed at their disposal. A thrush or blackbird will probably account for hundreds of grubs of various insect pests in the course of a day, if the ground has been turned up so that they are readily detected. Even the cost of digging the soil should not be debited to the birds, but to the cultivator himself, as it is he who obtains the additional advantage of having a larger supply of nitrates, phosphates, potash, fresh air, and other essential plant foods placed at the disposal of his crops. As some pests are dormant in the soil at every season of the year the wisest plan therefore to secure their eradication is to keep the upper layer stirred with the fork, spade, hoe, or scarified as often as the growing crops will permit. The hoe is probably the most convenient for keeping the surface of the soil in a loose and friable condition after digging or trenching. Its constant

use will prevent any pests from going to sleep too long, as they will be brought to the surface and exposed to the keen sight of the birds. The hoe, therefore, may be regarded not only as better than the hose pipe or water pot for keeping moisture in the soil, but it must also be considered as a far superior and more effectual destroyer of ground pests than most of the insecticides or earth powders recommended for this purpose. The work of hoeing between the crops will of course entail expense, but the money spent in this way will be found to yield more satisfactory results than twice the amount spent in misapplying insecticides of doubtful efficacy. The cultivator has to consider whether it will be better for him to stir the soil frequently, so as to expose the various grubs to his friends the birds (at the same time liberating food, keeping down weeds, and conserving moisture), or whether he will allow the soil to remain untilled and infested with pests that will in due course compel him to spend a good deal of money in washes and sprays, or lose his crops altogether. After all, the whole question is a matter of pounds, shillings, and pence, and the cultivator will find it more advantageous in every way to spend his money in frequent digging and hoeing operations, if he wishes to secure clean, healthy crops that are free from attacks of noxious insects. The advantages of cultural operations have been already discussed at pp. 101 to 107.

Table of Insect Pests.—The following tabulated statement of the various insect pests may be of use to the cultivator. Special stress is laid upon the Period of Rest (chrysalis stage) column. That is when the soil should be kept stirred up with the hoe, even if it cannot be dug with the spade or the fork. It is of course understood that one of the objects in stirring the soil is to enable the birds to get at the grubs. The column indicating Period of Destruction (the larval stage), is useful as indicating the period when the various washes and sprays are likely to be most effectual.

INSECT PESTS OF FRUITS, FLOWERS, AND VEGETABLES

Name of Pest.	Resting Period (Pupa Stage).	Destructive Period (Caterpillar and Perfect Insect Stage).	Plants Attacked and Remedies.
American Blight (*Schizoneura lanigera*, fig. 92).	Winter.	July to Oct.	Stems and roots of Apple trees. Caustic washes in winter, and methylated spirits or paraffin in summer.
Ants.	—	Jan. to Dec.	Troublesome in fruit- and plant-houses. Trap with sweet liquids, and strew lime about nests.
Aphides. *See* Green and Black Fly.			
Apple Aphis *and* Apple Sucker (*Aphis* and *Psylla Mali*).	Aug. to May.	May to July.	Attack flower buds and leaves. Syringe with lime and salt, or nicotine and quassia solutions.

Insect Pests of Fruits, Flowers, and Vegetables (*Cont.*)

Name of Pest.	Resting Period (Pupa Stage).	Destructive Period (Caterpillar and Perfect Insect Stage).	Plants Attacked and Remedies.
Apple-blossom Weevil (*Anthonomus pomorum*, fig. 97).	Winter.	Spring to Summer.	Attacks Apple buds, and afterwards the leaves. Grease-banding and hoeing in autumn and winter; also apply caustic wash before buds break in spring.
Apple and Currant Clear-wing Moth (*Trochilium myopœforme*, fig. 103).	Nov. to May.	June to Nov.	Grubs feed upon stems of the plants and the pupæ nest in the crevices. Use nicotine or quassia washes in summer, and caustic washes in winter, rubbed well into bark.
Apple Mussel Scale (*Mytilaspis pomorum*, fig. 93).	Winter.	May to Aug.	Bark and branches of Apple and other fruit trees. Apply caustic washes in winter.
Apple-pith Moth (*Tineina*).	Winter.	Spring to Autumn.	Early in year caterpillars tunnel into pith of shoots and fruit spurs, and pupate from June onwards. Spray with nicotine washes early in year, and cut back shoots in winter.
Apple Sawfly (*Hoplocampa testudinea*).	Aug. to Mar.	April to July.	Attacks flowers of Apple, and afterwards fruit. Destroy diseased fruit and stir ground frequently with hoe. Strew quicklime over surface.
Asparagus Beetle (*Crioceris Asparagi*, fig. 94).	Sept. to June.	June to Sept.	Attacks Asparagus shoots. Knock off with stick, and strew lime and soot over ground in advance. Spray with nicotine, or dust with hellebore powder.
Asparagus Fly (*Platyparea pœciloptera*).	Sept. to April.	April to Aug.	Larvæ bore into heads and stems of young shoots and work downwards. Cut and burn the stunted yellowish or brown stems, and syringe early in season with paraffin emulsion.
Bean Beetles (*Bruchus granarius* and *B. rufimanus*, fig. 95).	Oct. to April, in the seeds.	May to Oct.	Examine affected seeds and burn.
Beet Carrion Beetle (*Silpha opaca*).	Sept. to May.	May to Sept.	Woodlice-like larvæ attack young plants. Keep under with nicotine or quassia sprays and frequent hoeing.
Beet Fly (*Anthomyia Betæ*).	Sept. to May.	May to Sept.	The maggots feed upon the leaves of Beet. Remedies as for the Beet Carrion Beetle.
Black Aphis, Black Dolphin, Collier Blight, &c. (*Aphis Rumicis*).	Autumn to Spring.	May to Sept.	Attacks the shoots of Broad and Long Pod, Dwarf or French, and Runner Beans. Syringe with quassia and nicotine solutions in advance, and keep ground hoed. Infested shoots should be taken off and burned.
Black *or* Vine Weevil (*Otiorhynchus sulcatus*, fig. 152).	Mar. to July.	Aug. to Spring.	Attacks the roots, shoots, leaves, and flowers of various plants—frequently the Strawberry and Vine. Trap by shaking from Vines on to cloths and burning. Cultivate well in the open.

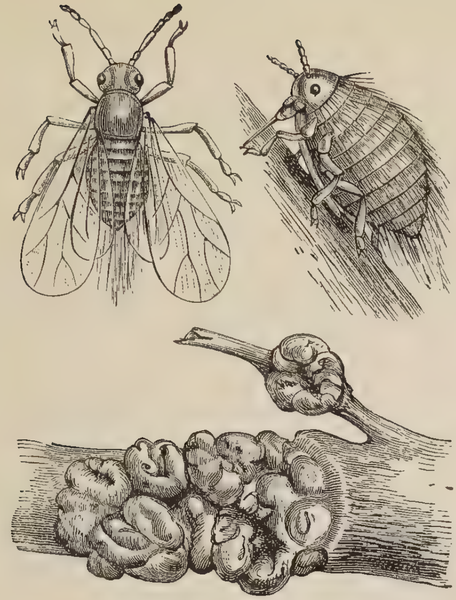


Fig. 92.—American Blight (*Schizoneura lanigera*)

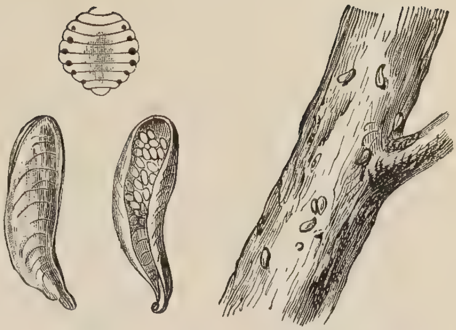


Fig. 93.—Apple Mussel Scale (*Mytilaspis pomorum*)

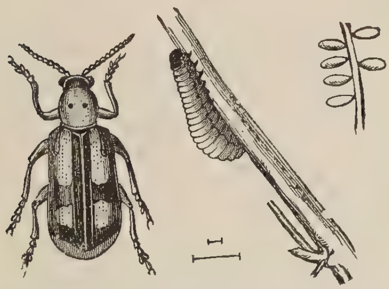


Fig. 94.—Asparagus Beetle (*Crioceris Asparagi*) Larva and eggs magnified.

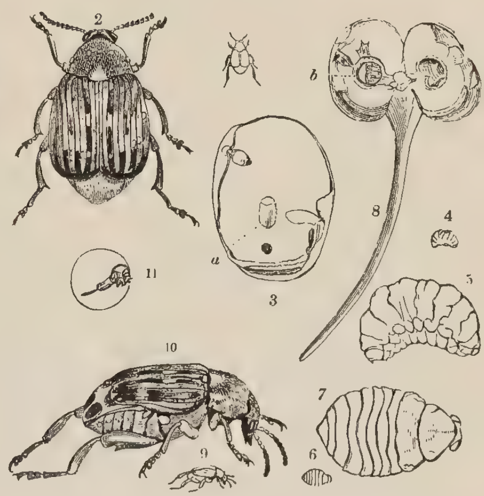


Fig. 95.—Bean Beetles

1, *Bruchus granarius* (nat. size); 2, magnified. 3 Section of infested Bean. 4, Maggot (nat. size); 5, enlarged. 6, Pupa (nat. size); 7, enlarged. 8, Infested Bean germinating. 9, *Bruchus rufimanus* (nat. size); 10, enlarged. 11, Infested Pea. 4, 5, 6, 7, are common to both species.

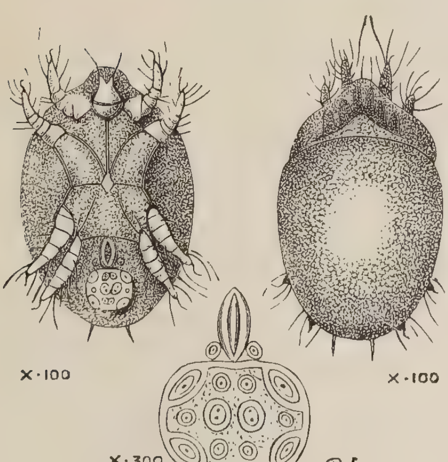


Fig. 96.—Bulb Mite (*Rhizoglyphus echinopus*). Dorsal and Ventral surfaces. The detached sucker-plate magnified 300 diameters. (After Michael.)

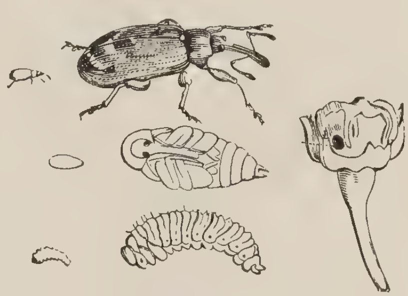


Fig. 97.—Apple-blossom Weevil (*Anthonomus pomorum*)

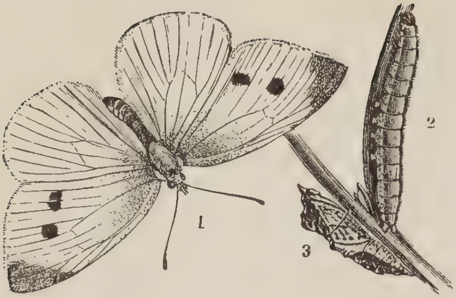


Fig. 98.—Cabbage Butterfly (*Pieris Rapæ*)

1, Small White Cabbage Butterfly. 2, Caterpillar. 3, Pupa.

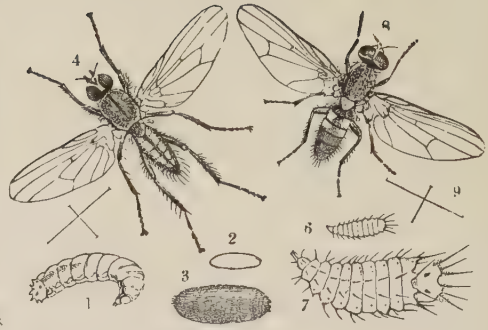


Fig. 99.—Cabbage Fly (*Anthomyia Brassicæ*)

1, Larva of *A. Brassicæ.* 2 and 3, Pupæ (nat. size and magnified). 4, *A. radicum* (magnified). 5, Nat. size. 6–9, *A. tuberosa*, larva and fly (nat. size and magnified).

Fig. 100.—Cabbage Gall Weevil (*Ceutorhynchus sulcicollis*)

1, Earth case of the larva. 2, Case in its chamber (magnified). 3, Stem with galls.

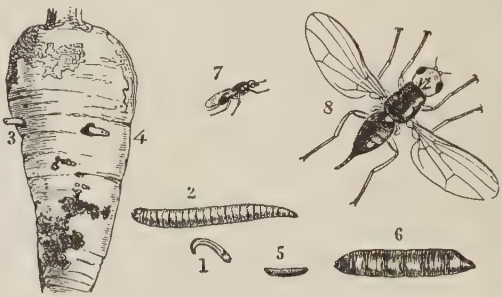


Fig. 101.—Carrot Fly (*Psila Rosæ*)

1, Larva; 2, magnified. 3 and 4, Larvæ appearing from the galleries excavated in the Carrot. 5, Form of pupa; 6, magnified. 7 and 8, The Fly (nat. size and magnified).

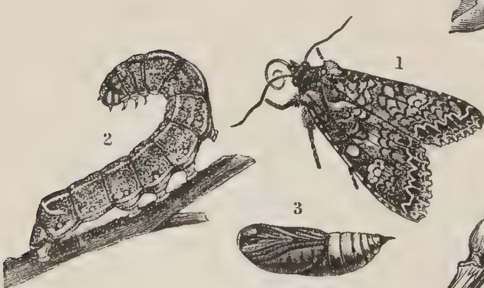


Fig. 102.—Cabbage Moth (*Mamestra Brassicæ*)

1, Moth. 2. Caterpillar. 3, Chrysalis.

Fig. 103.—Apple and Currant Clear-wing Moth (*Trochilium tipuliforme*), and Larva

INSECT PESTS OF FRUITS, FLOWERS, AND VEGETABLES (*Cont.*)

Name of Pest.	Resting Period (Pupa Stage).	Destructive Period (Caterpillar and Perfect Insect Stage).	Plants Attacked and Remedies.
Brown-tail Moth (*Porthesia chrysorrhœa*).	Oct. to May.	May to Oct.	The hairy larvæ feed upon fruit and forest trees. Nest in leaves in winter. Spray with arsenate of lead, &c.
Bulb Mite (*Rhizoglyphus echinopus*, fig. 96).	-	Jan. to Dec. under glass.	Mites attack bulbs of Eucharis and other plants, causing red blotches. Badly infested bulbs should be burned. Others should be washed in carbolic, lysol, cyllin, or paraffin solutions.
Cabbage Aphis (*Aphis Brassicæ*).	Winter to Spring.	Spring to Autumn.	Attacks Turnips and Cabbage crops generally. Spray with nicotine or quassia washes, and hoe frequently.
Cabbage Butterfly (*Pieris Brassicæ*, *P. Rapæ*, &c., fig. 98).	Oct. to Mar.	April to Sept.	Caterpillars attack various Cabbage crops. Ground should be well cultivated, and quassia or nicotine sprays may be used. Hand picking advisable for small patches.
Cabbage Flea, Blue (*Haltica consobrina*).	Autumn to Spring.	Spring to Autumn.	Cultivate soil well in autumn and winter, and also between crops in summer.
Cabbage Fly (*Anthomyia Brassicæ*, fig. 99).	Dec. to Feb.	Mar. to Nov.	Grubs attack fleshy roots of Turnips, Radishes, Cabbages, Cauliflowers, &c., and cause leaves to turn yellow and wilt. Badly infested plants should be burned. The best remedy is frequent hoeing amongst crops when possible.
Cabbage Gall Weevil (*Ceutorhynchus sulcicollis*, fig. 100).	Oct. to Feb.	Mar. to Sept.	Small white maggots attack lower portion of stems of Cabbages, Brussel Sprouts, Cauliflowers, Turnips, and others, and cause pea-like swellings. Best remedy is to hoe ground frequently between crops. Burn all infested stems in autumn.
Cabbage Moth (*Mamestra Brassicæ*, fig. 102).	Winter and early Spring.	Summer and Autumn.	Caterpillars destroy Cabbage crops in summer and autumn. Cultivate between crops in dormant season, and use lime and soot over ground.
Cabbage Powdered-wing Fly (*Aleyrodes proletella*).	Autumn to Spring.	Spring to Autumn.	Cabbage crops attacked. Remedies as for Cabbage Moths and Butterflies.
Cabbage-root Fly (*Phorbia brassicæ*).	Oct. to Mar.	April to Oct.	Attacks roots of Cabbage crops. Remedies as for Cabbage Gall Weevil.
Carnation Maggot (*Hylemyia nigrescens*).	Winter and Spring.	July to Sept.	Cylindrical maggots pierce down centre of Carnation and Pink stems. Spray with nicotine washes about July, and destroy badly affected plants. Hoe between crops frequently in autumn.
Carrot Aphis (*Aphis Dauci*).	Autumn and Spring.	June to Aug.	Attacks Carrot leaves. Spray before June with paraffin emulsion, and hoe frequently.
Carrot-blossom Moth (*Depressaria Pastinacella*).	Autumn and Winter.	July to Sept.	Attacks flowers of Carrots and Parsnips. May be caught with tarred sacks, or killed by hellebore powder.

INSECT PESTS OF FRUITS, FLOWERS, AND VEGETABLES (*Cont.*)

Name of Pest.	Resting Period (Pupa Stage).	Destructive Period (Caterpillar and Perfect Insect Stage).	Plants Attacked and Remedies.
Carrot Fly (*Psila Rosæ*, fig. 101).	Dec. to Feb.	Mar. to Dec.	Maggots attack roots of Carrots, and can only be kept down by frequent hoeings to expose them to birds. Infested roots should be burned. Spray early with paraffin emulsion.
Carrot-seed Moth (*Depressaria depressella*).	Autumn and Winter.	July, Aug.	Devours flowers and seeds of Carrots and Parsnips, especially latter. Spray with paraffin emulsion early in season a few times.
Celery and Parsnip Fly (*Acidia heraclei* or *Tephritis Onopordinis*, fig. 106).	Oct. to April.	April to Sept.	Eggs laid upon leaves of Parsnips and Celery hatch a grub that penetrates tissues. May be prevented by spraying with paraffin emulsion before April, and at intervals afterwards. Infected leaves must be collected and burned. Cultivate soil well, and strew with lime or soot.
Celery-stem Fly (*Riophila Apii*).	Oct. to April.	April to Sept.	Tunnels down stalks and makes rusty marks. Remedies as for Celery Fly.
Cherry Aphis (*Myzus Cerasi*).	Autumn to Spring.	Summer.	This is the Black Fly of Cherries. Trees must be well syringed with nicotine or quassia solutions.
Cherry Sawfly. *See* Pear Sawfly.			
Chrysanthemum Leaf-miner (*Phytomyia nigricornis*, figs. 104 and 105).	Oct. to Mar.	April to Oct.	Chiefly attacks Chrysanthemum and Marguerite leaves, the maggot boring between the tissues. Prevention and cure as for Celery Fly.
Cockchafer *or* May Bug (*Melolontha vulgaris*).	—	Jan. to Dec.	Large fleshy white grubs that take three years to attain full size. They feed on roots of fruit trees, Roses, &c., and do much damage. The perfect beetles feed on leaves of Apple and other trees in May and June. Digging brings grubs up to birds, but they should be collected when possible and burned. Perfect insects should be shaken from trees on to sheets, collected, and burned.
Cockroach (*Blatta orientalis*).	—	Jan. to Dec.	Destroys flowers of various kinds. May be trapped in glasses with beer, molasses, &c. Houses should be cleaned and limewashed.
Codlin Moth (*Carpocapsa Pomonella*, fig. 107).	Autumn to Spring.	June to Sept.	Eggs laid in Apple flowers, and maggots afterwards spoil fruit. Collect all diseased fruits and burn. Spray with Paris green, arsenate of lead, &c., when trees are in bloom. Cleanse stems with caustic wash in winter. Hoe ground frequently during autumn and winter.
Cranefly. *See* Daddy Longlegs.			

Fig. 104.—Chrysanthemum Leaf-miner (*Phytomyza nigricornis*)

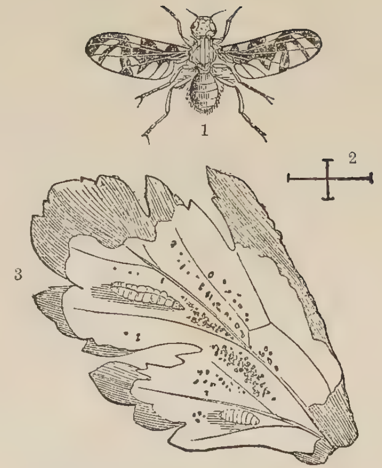


Fig. 106.—Celery Fly (*Tephritis Onopordinis*)

1, Fly (magnified). 2, Lines showing natural size. 3, Larva and pupa figured on blistered leaf.

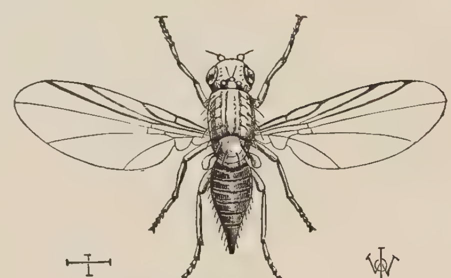


Fig 105.—Chrysanthemum Leaf-miner (*Phytomyza nigricornis*), the perfect insect.

Fig. 107.—Codlin Grub and Moth (*Carpocapsa Pomonella*).

Moth (1) and larva (2) enlarged. 3, Larva escaping from injured apple. 4, Shows cocoon, chrysalis, and young fruit with maggot entering.

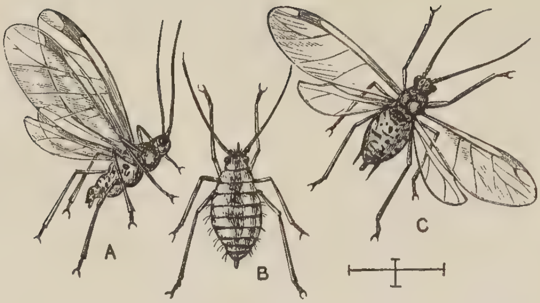


Fig. 108.—Currant Aphis (*Myzus Ribis*)

A, Male. B, Apterous female. C, Winged female.

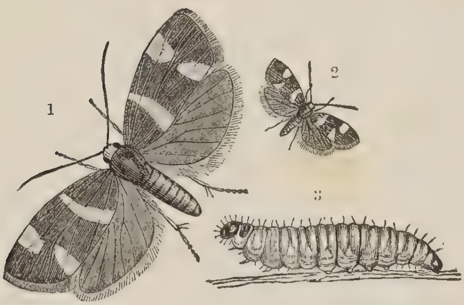


Fig. 109.—Currant-shoot Moth (*Incurvaria capitella*)

1 Moth (magnified). 2, Moth (nat. size). 3, Caterpillar (magnified).

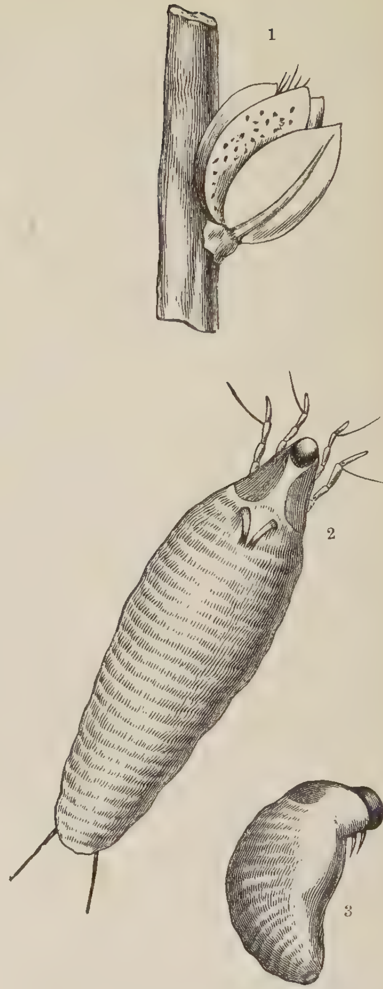


Fig. 110.—Currant Gall Mite (*Eriophyes Ribis*)

1, Infested bud. 2, Mite (greatly enlarged). 3, Mite (younger stage).

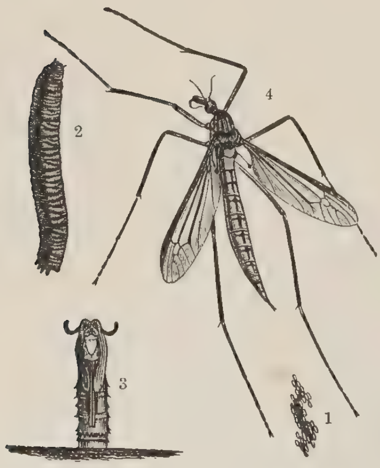


Fig. 111.—Daddy Longlegs or Craneflies (*Tipula oleracea* and *T. paludosa*)

1, Eggs. 2, Maggot. 3, Pupa-case vacated by the gnat of *Tipula oleracea*. 4, Female of *Tipula paludosa*.

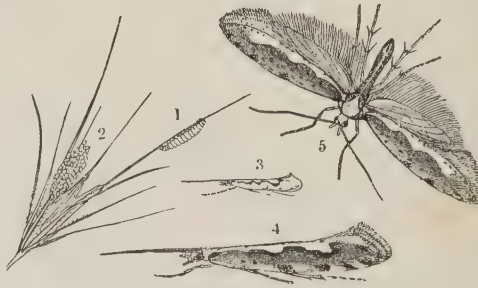


Fig. 112.—Diamond-back Moth (*Plutella cruciferarum*)

1, Caterpillar; 2, Eggs; 3, Moth (all natural size). 4, 5, Moth (magnified), at rest and flying.

INSECT PESTS OF FRUITS, FLOWERS, AND VEGETABLES (*Cont.*)

Name of Pest.	Resting Period (Pupa Stage).	Destructive Period (Caterpillar and Perfect Insect Stage).	Plants Attacked and Remedies.
Currant and Gooseberry Sawfly (*Nematus Ribesii*, fig. 119).	Sept. to Mar.	April to Sept.	Larvæ eat leaves of Red Currants and Gooseberries. Dust with lime, sulphur, soot, hellebore, &c. Cultivate soil well from October to April to bring up pupæ for birds.
Currant Aphis (*Myzus Ribis*, fig. 108).	Autumn and Winter.	Spring and Summer.	Troublesome pests on the under surface of leaves of Red, White, and Black Currants. Syringe well with nicotine solutions, and cultivate ground with hoe.
Currant and Apple Clear-wing Moth (*Trochilium tipuliforme*, fig. 103).	April to June.	Oct. to April.	The grubs pierce the young wood and feed upon the pith. The affected shoots should be cut off and burned. Spray with nicotine washes, &c., in June to prevent eggs being laid by female.
Currant Gall Mite (*Eriophyes* [*Phytoptus*] *Ribis*, fig. 110).	Winter.	April to Oct.	Attacks young flower buds of Black Currant, and causes "big bud". Pick off big buds, and dust with lime and sulphur two or three times in spring.
Currant-root Aphis (*Schizoneura fodiens*).	Winter.	Spring to Autumn.	Attacks roots of Black and Red Currants. Cultivate soil well, and occasionally drench with soapy water.
Currant Scale, White Woolly (*Pulvinaria Ribesiæ*).	Nov. to Mar.	April to Oct.	Attacks Black, Red, and White Currants, especially when grown on walls or fences. The pest forms whitish woolly masses and webs. Apply caustic washes in winter, and paraffin emulsion early in year.
Currant-shoot Moth (*Incurvaria* or *Tinea capitella*, fig. 109).	Oct. to April.	April to Sept.	The caterpillars feed on the pith of young shoots of Red and White Currants. Cut off diseased shoots and burn. Spray with nicotine, &c., in May, when female lays eggs.
Daddy Longlegs *or* Cranefly (*Tipula oleracea* and *T. paludosa*, fig. 111).	Oct. to April.	May to Oct.	The maggots, known as "leather jackets", eat the roots of many plants, and infest Turnips, Beet, Potatoes, &c. Deep cultivation, hoeing, and encouragement of birds are the best remedies. Otherwise trap with turnips, beet, potatoes, &c.
Dart Moths (*Agrotis exclamationis*, *A. segetum*, figs. 113 and 114).	Oct. to May.	May to Nov.	Caterpillars eat roots of all kinds of plants, feeding at night. Strew lime and soot over soil, and hoe frequently.
Diamond-back Moth (*Plutella maculipennis*, *P. cruciferarum*, fig. 112).	Oct. to May.	June to Sept.	Green or yellowish caterpillars eat away leaves of Cabbages, Turnips, &c. Dust with soot or lime, or spray with quassia and soft-soap solutions. Cultivate soil in dormant season.
Earwigs (*Forficula auricularia*).	Winter.	Spring to Autumn.	Various flowers and fruits at night-time. Stir ground frequently, and trap with pieces of cloth, hay, &c., in pots. Deep cultivation and frequent hoeing excellent remedies.

Insect Pests of Fruits, Flowers, and Vegetables (*Cont.*)

Name of Pest.	Resting Period (Pupa Stage).	Destructive Period (Caterpillar and Perfect Insect Stage).	Plants Attacked and Remedies.
Eelworm, Nematoid Worms (*Tylenchus devastatrix*, *Heterodera radicicola*, *H. Schachti*, fig. 116).	—	Jan. to Dec.	Minute snake-like larvæ that prey upon the roots of many garden crops, notably Cucumbers, Tomatoes, Phloxes, Gardenias, Carnations, &c. Apply lime or soot or basic slag to badly infested soil, and avoid too rich organic manures. *See* article on "Cucumber", Vol. IV.
Eucharis Mite. *See* Bulb Mite.			
Figure-of-8 Moth (*Diloba cæruleocephala*, fig. 118).	Sept. to May.	May to Aug.	Larvæ attack leaves of Apple and other fruit trees. Spray with Paris green, arsenate of lead, &c., in May and June. Cultivate the soil in dormant season.
Fruit-tree Beetle (*Scolytus rugulosus*).	Oct. to April.	April to Oct.	Small larvæ tunnel between the bark and wood of Apples, Pears, Plums, Cherries, Peaches, Nectarines, and other Rosaceous trees. Cut down and burn badly infested trees. Use hot caustic wash in winter, and cultivate soil well in summer.
Garden Chafer (*Phyllopertha horticola*).	July to April.	May to July.	Larvæ feed upon leaves of Roses, fruit trees, &c. Spray with quassia, nicotine, &c., in May and June. Hoe during summer to bring up pupæ for birds.
Garden Pearl Moth (*Pionea forficalis*).	Oct. to June.	June to Oct.	Larvæ feed on leaves of Cabbage crops, Turnips, Horse Radish. Dust with lime or soot, or spray with nicotine or other washes. Cultivate soil well up to June.
Ghost-swift Moth (*Hepialus Humuli*, fig. 115).	May to July.	Aug. to April.	Caterpillars feed upon roots of Lettuces, Strawberries, Hops, Nettles, &c., and cause leaves to wilt. Hoe frequently from August to April, and destroy all nettles and other weeds.
Goat Moth (*Cossus ligniperda*).	Winter months.	Spring to Autumn.	Fat caterpillar, 3–4 in. long, with a goat-like smell, pierces trunks of fruit and forest trees, and lives in them for three years. Thrust wire into burrows, or inject strong petroleum washes.
Gooseberry Sawfly. *See* Currant Sawfly.			
Grape Moth (*Ditula angustiorana*, fig. 120).	Various.	Various.	Found on many trees, but chiefly destructive to Grape fruits. Shake caterpillars on to tarred paper, and burn.
Green and Black Fly (*Rhopalosiphon Dianthi*, *Siphonophora Pelargoni*, *S. Pisi*, *Aphis Cratægaria*, &c.).	Winter in open air.	Jan. to Dec. under glass.	Numerous garden plants infested with various species of green fly, in the open air and under glass. Fumigate under glass. Syringe with quassia and soft soap or nicotine solutions in open air.
Julus Worms. *See* Millipedes.			

Fig. 113.—The Common Dart Moth (*Agrotis segetum*)

1, Moth flying. 2, Caterpillar.

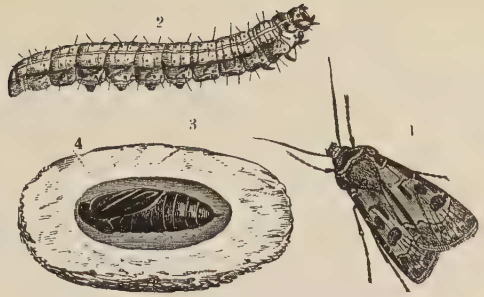
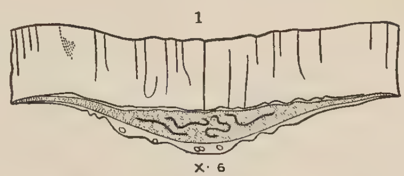
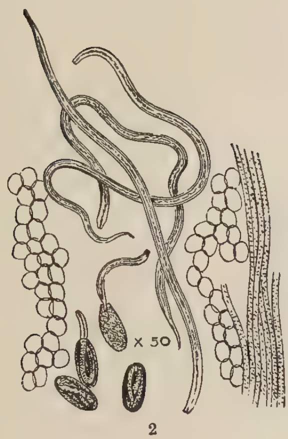


Fig. 114.—The Heart-and-dart Moth (*Agrotis exclamationis*)

1, Moth at rest. 2, Caterpillar. 3, Earthen case surrounding chrysalis. 4, Chrysalis.





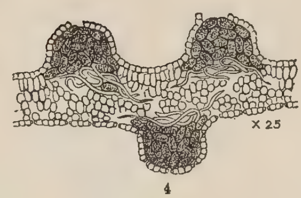


Fig. 115.—Ghost-swift Moth (*Hepialus Humuli*)

1 and 2, Eggs (nat. size and magnified). 3, Caterpillar. 4, Chrysalis. 5 and 6, Moths, male and female (nat. size).

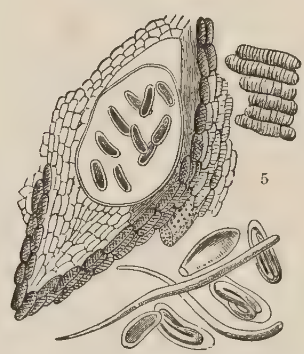


Fig. 116.—Eelworms or Nematoid Worms (*Tylenchus*)

1, Transverse section of Carnation leaf, showing eelworms in the tissue. 2, Portion of Carnation leaf (magnified 50 times), showing worms escaping from the eggs and also fully developed. 3, Surface view of leaf of Oncidium, showing egg-containing pustules bursting. 4, Transverse section of leaf of Oncidium, showing eggs containing worms ready to hatch out in pustules on both surfaces, and worms in the tissues. 5, Portion of root of Cucumber (highly magnified), showing a cyst containing eggs in the centre; also eggs at the lower right-hand corner from which the worms are escaping, and worms that have escaped.

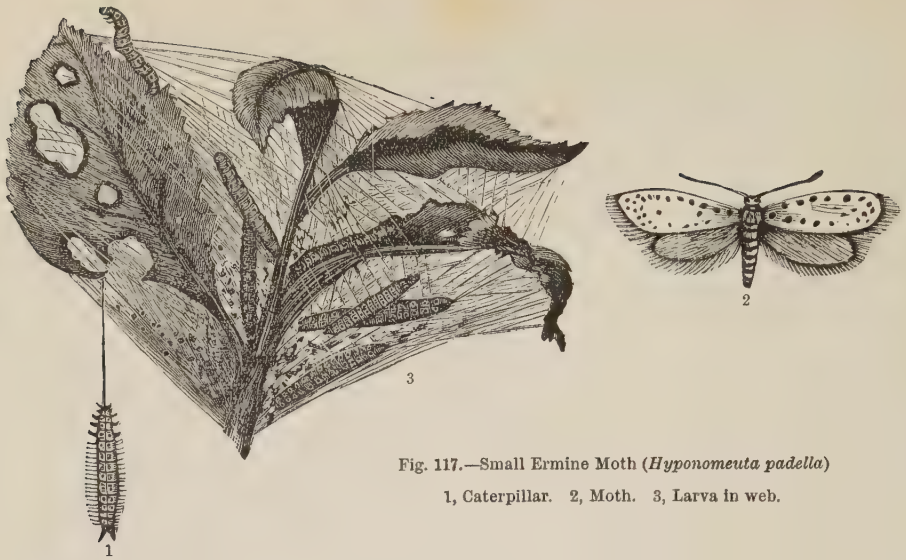


Fig. 117.—Small Ermine Moth (*Hyponomeuta padella*)

1, Caterpillar. 2, Moth. 3, Larva in web.

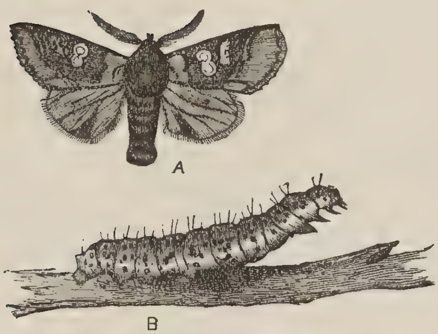


Fig. 118.—Figure-of-8 Moth (*Diloba cœruleocephala*)

A, Moth. B, Caterpillar.

Fig. 119.—Gooseberry and Currant Sawfly (*Nematus Ribesii*)

1, Shoot of Gooseberry. 2, Eggs. 3, Larva. 4, Pupa. 5, Perfect Insect.

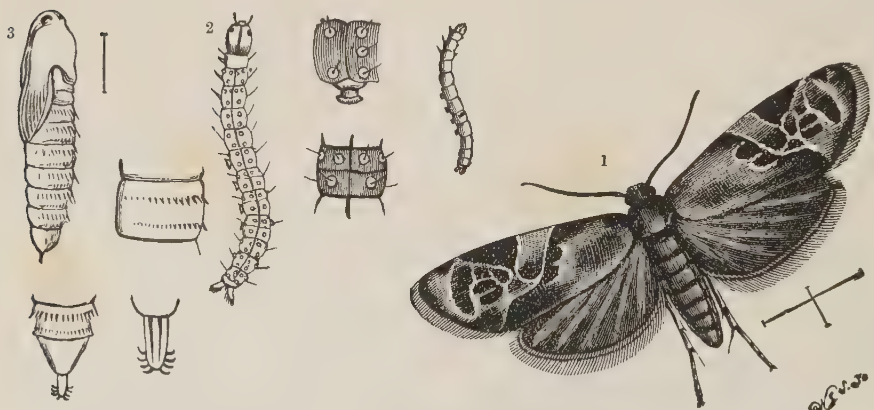


Fig. 120.—Grape Moth (*Ditula angustiorana*)

1, Moth. 2, Larva and details. 3, Chrysalis (all enlarged).

INSECT PESTS OF FRUITS, FLOWERS, AND VEGETABLES (*Cont.*)

Name of Pest.	Resting Period (Pupa Stage).	Destructive Period (Caterpillar and Perfect Insect Stage).	Plants Attacked and Remedies.
Lackey Moth (*Clisiocampa neustria*, fig. 121).	July to April.	April to July.	Larvæ feed upon leaves of fruit and forest trees. Eggs on branches should be looked for in April and destroyed. Spray with quassia and soft soap in May and June. Collect cocoons from trees in July and August, and burn.
Lettuce Fly (*Anthomyia Lactucæ*).	Oct. to April, in Lettuce heads.	April to Oct.	Attacks flowers of Lettuce plant when grown for seed. Cultivate well, and destroy all old Lettuce stems.
Lettuce-root Aphis (*Pemphigus lactuarius*).	Winter.	April to Sept.	Larvæ pass from leaves to roots and feed upon them. Lime, or soot, or soft soapy water good remedies; also frequent hoeing.
Magpie Moth (*Abraxas grossulariata*, fig. 123).	Oct. to July.	Aug., Sept.	Larvæ feed upon leaves of Red and White Currants, Gooseberries. Examine bushes for pupæ which hang down from Sept. to July, and burn all collected. Spray bushes with Paris green, arsenate of lead, &c., in Aug. and Sept. before first attack.
March Moth (*Anisopteryx æscularia*). *See* Winter Moth for habits and remedies.			
May Bug. *See* Cockchafer.			
Mealy Bug (*Dactylopius adonidum*).	—	Jan. to Dec.	A hothouse pest of stove and greenhouse plants, Vines, &c. Paraffin washes and fumigation.
Millipedes *or* Julus Worms (Species of *Julus* and *Polydesmus*, fig. 131).	—	Jan. to Dec.	The larvæ (often called wireworms) feed upon roots of Potatoes, Onions, Carrots, Turnips, Cabbages, &c. Best remedy frequent hoeing, and strewing lime or soot on ground, and avoid rank manure.
Mole Cricket (*Gryllotalpa vulgaris*, fig. 125).	Oct. to May.	June to Sept.	Larvæ attack roots of vegetable crops, and also caterpillars and other insects, and may be discovered by small heaps of mould. They may be caught by placing hot manure in deep holes, in Sept., and when insects have nested they may be dug out. Frequently hoe ground.
Mottled Umber *or* Great Winter Moth (*Hybernia defoliaria*, fig. 122). *See* also "Winter Moth", fig. 144.	Nov. to April.	April, May, and June for larvæ; Oct., Nov. for egg laying.	Larvæ feed upon leaves of Apples, Pears, Plums, Roses, &c. In Oct. and Nov. eggs are laid on shoots, which should be washed with caustic soda; ground should be well hoed during summer. Grease-banding useful in Oct.
Narcissus Fly (*Merodon Narcissi*, fig. 124).	Nov. to Feb.	Mar. to Nov.	Maggots attack bulbs of Narcissi. Affected bulbs are best burned. Hoe soil between crops, and place saucers of sweet solutions between Narcissi to trap perfect flies.

Insect Pests of Fruits, Flowers, and Vegetables (*Cont.*)

Name of Pest.	Resting Period (Pupa Stage).	Destructive Period (Caterpillar and Perfect Insect Stage).	Plants Attacked and Remedies.
Nematoid Worms. *See* Eelworms.			
Nut Weevil (*Balaninus nucum*).	Autumn to Spring.	Spring and Summer.	Cultivate the soil, and shake diseased fruits on to cloths beneath trees in May and June, and destroy.
Onion Fly (*Anthomyia ceparum* or *Phorbia cepetorum*).	Autumn to Spring.	Spring to Autumn.	Larvæ penetrate Onion bulbs and cause leaves to flag. Destroy affected bulbs and hoe ground frequently between plants. Strew lime or soot, and spray with petroleum emulsion early in the season.
Onion Fly, Brassy (*Eumerus æneus*, fig. 126).	Oct. to Mar.	April to Sept.	Grubs attack bulbs of Onions during season. Destroy injured bulbs, and cultivate soil with hoe in summer and winter.
Parsnip Fly. *See* Celery Fly.			
Pea and Bean Weevil (*Sitones lineata*, *S. crinita*, fig. 132).	Sept. to Mar.	Mar. to Sept.	Weevils destroy leaves of Peas and Beans. Dust with lime or soot, or spray with nicotine or quassia solutions.
Pea Moth (*Endopisa proximana*).	Sept. to May.	May to Sept.	Peapods are attacked, the caterpillars feeding on the peas in summer, and escaping into ground in autumn. Cultivate soil by digging and hoeing.
Peach Aphis (*Aphis Amygdali*, *Myzus Persicæ*).	Sept. to April.	April to Sept.	Attacks young leaves and causes them to curl. Fumigate under glass. Syringe frequently with nicotine washes in open air.
Peach Scale (*Lecanium Persicæ*).	Winter.	Spring and Summer.	The young shoots of Peach trees. Paraffin emulsion and caustic wash in winter.
Pear-leaf-blister Moth (*Lyonetia Clerckella*, fig. 130).	Oct. to April.	April to Oct.	Pale-green larvæ mine the leaves of Apples, Pears, Cherries, forming tunnels and blisters. Spray with Paris green, nicotine, arsenate, or other washes in April, May, and June. Cultivate soil well in winter and spring.
Pear-leaf Mite (*Phytoptus Pyri*, fig. 127).	Autumn to Spring.	Spring to Autumn.	This minute pest penetrates leaf tissues of Pear, causing spots and blotches. Remedies for Currant Gall Mite may be tried.
Pear Midge (*Cecidomyia* or *Diplosis pyrivora*).	Autumn to Spring.	Spring and Summer.	Eggs are laid in blossoms, and the yellow maggots feed on young fruits, sometimes twenty to thirty in one fruit. Spray with Paris green, arsenate of lead, &c., before flowers open. Collect diseased fruit, and cultivate soil well in dormant season.
Pear Oyster Scale (*Diaspis ostreæformis*, fig. 128).	Winter.	May to Aug.	Paraffin emulsion in summer, and caustic wash in winter, to cleanse the infested bark.

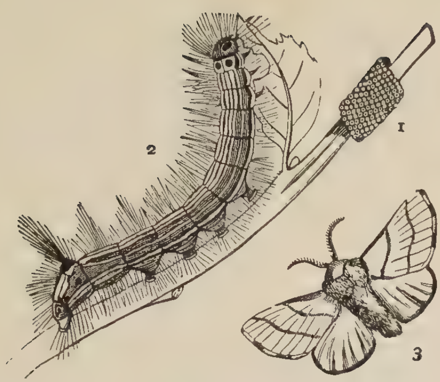


Fig. 121.—Lackey Moth (*Clisiocampa neustria*)

1, Eggs. 2, Caterpillar. 3, Moth.

Fig. 122.—Mottled Umber Moth (*Hybernia defoliaria*)

1. Male Moth. 2, Female. 3, Caterpillar (nat. size).

Fig. 123.—Magpie Moth (*Abraxas grossulariata*) and Larva

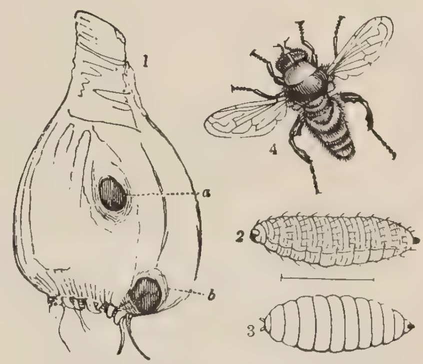


Fig. 124.—Narcissus Fly (*Merodon Narcissi*)

1, Infested bulb; *a* and *b*, grub holes. 2, Grub. 3, Pupa. 4, Insect.

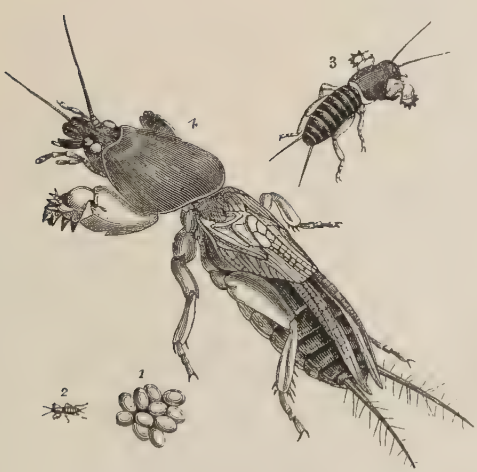


Fig. 125.—Mole Cricket (*Gryllotalpa vulgaris*)

1, Eggs. 2 and 3, Larvæ of different ages. 4. Mature Insect.

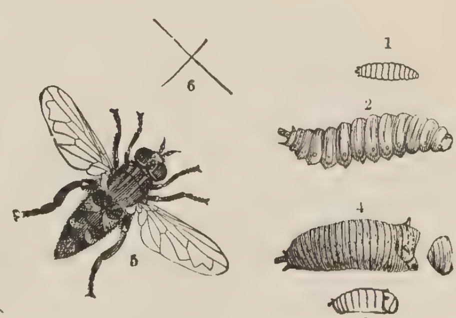


Fig. 126.—Brassy Onion Fly (*Eumerus æneus*)

1 and 2, Grub (nat. size and enlarged). 3 and 4, Pupa (nat. size and enlarged). 5 and 6, Insect (enlarged and nat. size).

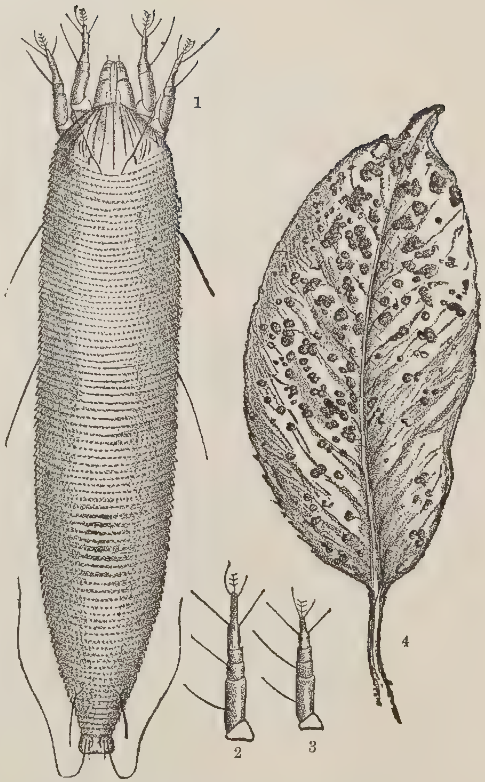


Fig. 127.—Pear-leaf Mite (*Phytoptus Pyri*)

1, Female. 2 and 3, Legs (magnified 550 times). 4, Infested Pear leaf.

Fig. 128.—Pear Oyster Scale (*Diaspis ostreæformis*)

Showing scales on shoot (nat. size), and insect and scales (greatly enlarged).

Fig. 129.—Pear Sucker (*Psylla Pyri*), magnified

Fig. 130.—Pear-leaf-blister Moth (*Lyonetia Clerckella*)

1, Blistered Pear leaf. 2, Caterpillar (nat. size); 3, magnified. 4, Pupa. 5, 6, Moth (nat. size and magnified).

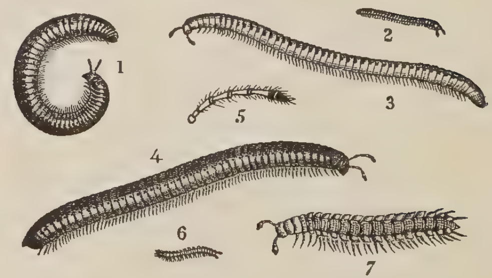


Fig. 131.—Millipedes or Julus Worms

1, *Julus londinensis*. 2 and 3, *J. guttatus* (nat. size and magnified). 4, *J. terrestris*; 5, horn (magnified). 6 and 7, *Polydesmus complanatus* (nat. size and magnified).

INSECT PESTS OF FRUITS, FLOWERS, AND VEGETABLES (*Cont.*)

Name of Pest.	Resting Period (Pupa Stage).	Destructive Period (Caterpillar and Perfect Insect Stage).	Plants Attacked and Remedies.
Pear Sawfly (*Eriocampa limacina*).	Oct. to May.	May to Oct.	Black slimy caterpillars feed upon under surface of Pear leaves, Roses, &c. Spray freely with nicotine and quassia washes early in season. Cultivate soil well in dormant season.
Pear Sucker (*Psylla Pyri*, fig. 129).	Winter.	Spring and Summer.	Young leaves of Pears when coming into bloom. Nicotine washes in summer, and caustic in winter.
Phylloxera vastatrix. *See* Vine Louse.			
Plum Aphis (*Aphis Pruni*).	Sept. to April.	May to Aug.	Mealy-covered pests suck juices from leaves of Plums, and leave excreta on surface, and curl leaves. Spray freely from May onwards with nicotine, quassia, or other solutions.
Plum Grub (*Carpocapsa funebrana*, fig. 134).	Oct. to May.	June to Sept.	Caterpillars attack fruits, and pierce flesh to stone. Treat as for Plum Sawfly.
Plum Sawfly (*Hoplocampa fulvicornis*).	Autumn to Spring.	Mar. to July.	Feeds upon young Plum fruits and destroys them. Collect fallen fruits and burn. Cultivate from autumn to spring.
Plum Weevil. *See* Red-legged Garden Weevil.			
Raspberry Beetle (*Byturus tomentosus*, fig. 136).	Autumn and Winter.	Spring and Summer.	Fruits of Raspberry. Burn all diseased fruit, and hoe well round stools at intervals during the year.
Raspberry Moth (*Lampronia rubiella*, fig. 135).	Oct. to April.	April to Oct.	The pink larvæ, about ¼ in. long, feed on flower and leaf buds and pith of shoots. Destroy injured shoots which may contain grubs. Cultivate soil well in dormant season, and dust freely with lime or soot.
Raspberry Weevil (*Otiorhynchus picipes*). *See* Red-legged Garden Weevil.			
Red-legged Garden Weevil (*Otiorhynchus tenebricosus*).	May to July.	Aug. to April.	Larvæ feed upon roots of Gooseberries, Currants, Raspberries, Strawberries, Vines. Hoe ground frequently, and dust with lime or soot.
Red Spider (*Tetranychius telarius*; also species of *Bryobia* and *Tenuipalpus*).	Autumn to Spring outside.	Jan. to Dec. under glass.	Tiny mites infesting under surface of leaves of many plants in the open air and under glass. Syringe thoroughly with clean water or nicotine solution.
Root Aphis (*Trama troglodytes*).	Oct. to April.	May to Oct.	Feeds upon the roots of Jerusalem Artichokes and other plants. Best kept down by cultivation and hoeing.
Rootgall. *See* Eelworm.			

INSECT PESTS OF FRUITS, FLOWERS, AND VEGETABLES (*Cont.*)

Name of Pest.	Resting Period (Pupa Stage).	Destructive Period (Caterpillar and Perfect Insect Stage).	Plants Attacked and Remedies.
Rose Aphis (*Siphonophora Rosæ, S. rosarum*).	Oct. to Mar.	April to Sept.	Attacks leaves and young shoots of Roses in open air and under glass. Syringe freely with nicotine or quassia solutions.
Rose Chafer (*Cetonia aurata*, fig. 139).	Oct. to Mar.	April to Oct.	The fat, hairy, whitish grubs feed on roots of various plants, and the beetles feed on the flowers of Roses, Strawberries, &c. Remedies as for Cockchafer Grub.
Rose Sawflies (*Hylotoma Rosæ, Emphytus cinctus*, figs. 133 and 137).	Oct. to Mar.	April to Sept.	Larvæ eat leaves of Roses. Some Rose Sawflies roll the leaves up into shelters. Syringe early and frequently with nicotine or quassia washes. Cultivate from Oct. to March.
Rose Tortrix (*Lozotænia Rosana*).	Aug. to Mar.	April to July.	Larvæ roll up leaves of Roses and other plants, and feed upon the flower buds. Remedies as for Sawflies.
Silver Y Moth (*Plusia gamma*, fig. 140).	Oct. to Mar.	April to Sept.	Green caterpillars feed upon leaves of all kinds of plants. Spray with nicotine and other washes early; dust with lime or soot. Cultivate ground well in dormant season.
Slugs and Snails (*Limax ater, L. agrestis, Helix hortensis*).	—	Jan. to Dec.	Troublesome under glass and in open air. Catching by hand under glass, or strewing stages or soil with soot or lime as in open air. Use hoe frequently outside, and encourage thrushes, blackbirds, &c.
Slug Worms (*Eriocampa limacina, E. Rosæ*, fig. 138).	Oct. to June.	July to Oct.	Larvæ destroy leaves of Pears, Roses, &c. See remedies under Pear Sawfly.
Small Ermine Moth (*Hyponomeuta padella*, fig. 117); *H. euonymella, H. malinella*.	July to Mar.	April to June.	Caterpillars live in colonies in webs, and destroy leaves of Apples, Hawthorns, Euonymus, &c. Syringe freely in May with Paris green, nicotine, or other poisonous washes. Collect cocoons from plants in July and August. Cultivate ground during dormant season.
Snowy Fly (*Aleyrodes vaporariorum*).	—	Jan. to Dec.	Minute larvæ infest leaves of Cucumbers, Ferns, Tomatoes, &c., and perfect white insects soon develop. Fumigate and syringe with nicotine.
Spittle Fly *or* Frog Hopper (*Aphrophora spumaria*, fig. 142).	Oct. to April.	May to Sept.	Larvæ embedded in spittle-like froth suck juices from tender shoots of many garden plants. Brush off pests or squeeze between fingers. Afterwards spray with nicotine or quassia solutions.
Thrips (*Thrips minutissima, T. pisivora, T. cerealium*, &c., fig. 148).	Autumn to Spring in open air.	Jan. to Dec. under glass.	The dull yellow larvæ of several species attack under surface of leaves of many crops in open air and under glass when air is very dry. Syringe plants under glass with water or quassia solutions; also in open air; and hoe freely.

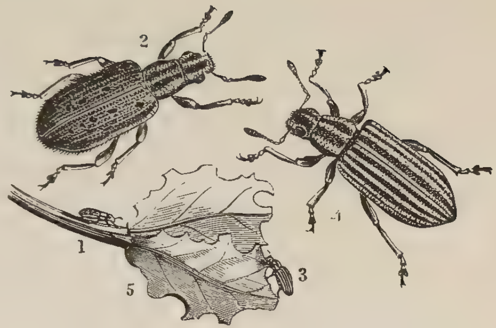


Fig. 132.—Spotted and Striped Pea Weevils (*Sitona crinita* and *S. lineata*)

1, Spotted Pea Weevil (nat. size); 2, magnified. 3, Striped Pea Weevil (nat. size); 4, magnified. 5, Leaf notched by Weevils.

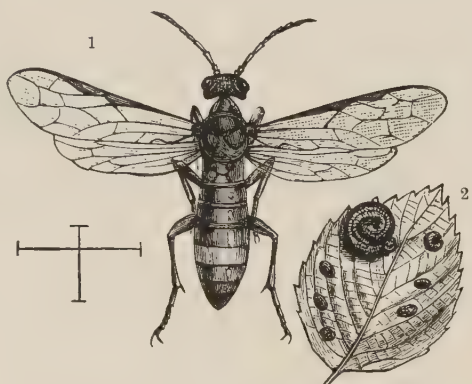


Fig. 133.—Rose Sawfly (*Emphytus cinctus*)

1, Insect enlarged. 2, Leaflet, showing larvæ.

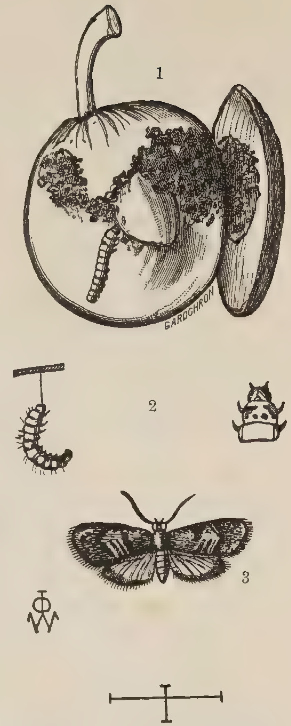


Fig. 134.—Plum Grub and Moth (*Carpocapsa funebrana*)

1, Fruit with grub. 2. Grub descending from trees (with enlarged head). 3, Moth.

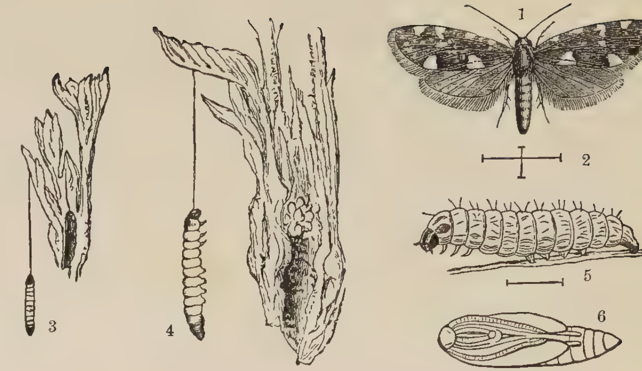


Fig. 135.—Raspberry Moth (*Lampronia rubiella*)

1, Moth (magnified); 2, nat. size. 3, Caterpillar (nat. size). 4, Caterpillar (enlarged). 5, Caterpillar (greatly magnified and nat. size). 6, Chrysalis (greatly magnified).

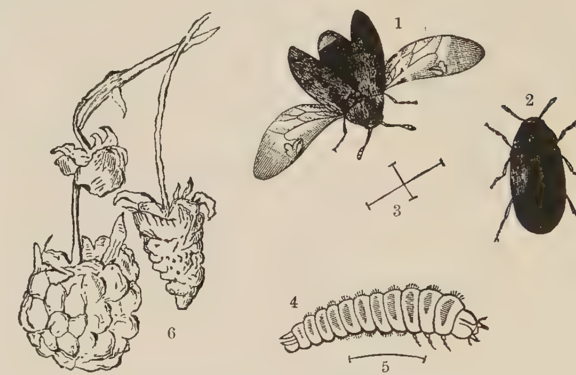


Fig. 136.—Raspberry Beetle (*Byturus tomentosus*)

1, 2, Raspberry Beetles (magnified); 3, nat. size. 4, Maggot (magnified); 5, nat. length. 6, Infested Raspberry fruit.

Fig. 137.—Larvæ of Rose Sawfly (*Hylotoma Rosæ*)

Fig. 138.—Slug Worm or Sawfly (*Eriocampa limacina*), showing enlarged insect, and larva on leaf.

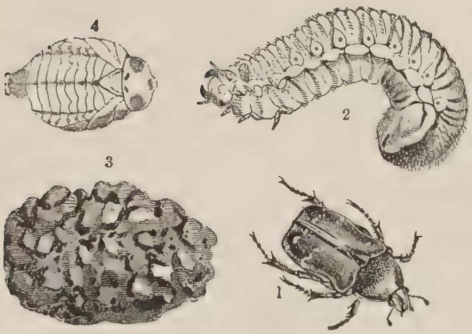


Fig. 139.—Rose Chafer (*Cetonia aurata*)

1, Beetle. 2, Caterpillar. 3, Cocoon. 4, Pupa.

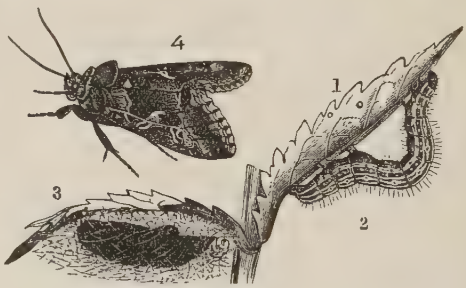


Fig. 140.—Silver Y Moth (*Plusia gamma*)

1, Eggs. 2, Caterpillar. 3, Chrysalis in cocoon. 4, Moth.

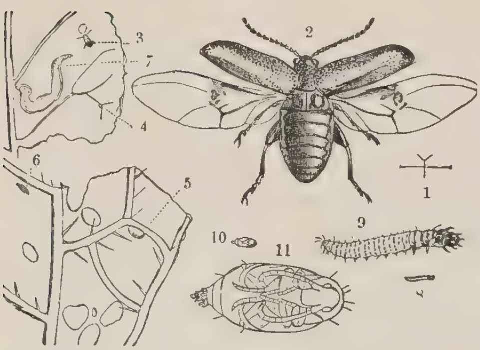


Fig. 141.—The Turnip Fly or Beetle (*Phyllotreta nemorum*)

1 and 2, Insect (nat. size and magnified). 3, Insect feeding. 4 and 5, Eggs on under side of leaf. 6 and 7, Maggot advancing in growth. 8 and 9, Maggot full-grown (nat. size and magnified). 10 and 11, Pupa (nat. size and magnified).

Fig. 142.—Spittle Fly (*Aphrophora spumaria*), showing insects and frothy spittle on shoot.

INSECT PESTS OF FRUITS, FLOWERS, AND VEGETABLES (*Cont.*)

Name of Pest.	Resting Period (Pupa Stage).	Destructive Period (Caterpillar and Perfect Insect Stage).	Plants Attacked and Remedies.
Turnip Fly (*Phyllotreta nemorum*, fig. 141).	Oct. to Mar.	April to Sept.	Maggots penetrate leaf tissues of Turnip crops, and mature in a week. Spray early with nicotine or quassia washes, and at frequent intervals hoe the soil to bring up the pupæ for the birds.
Turnip Gall Weevil (*Ceutorhynchus pleurostigma*, fig. 143).	Oct. to Feb.	Mar. to Sept.	Remedies as for Cabbage Gall Weevil.
Turnip Mud Beetle (*Helophorus rugosus*).	?Winter.	Spring to Autumn.	Beetles and grubs attack all parts of Turnip crops, especially tops of bulbs. Hoe frequently and dress with lime or soot, and burn diseased plants.
Turnip Sawfly (*Athalia spinarum*).	Oct. to Mar.	April to Sept.	Larvæ eat leaves of Turnips from edges to ribs. Numerous brood in one season. Remedies as for Turnip Fly.
V Moth (*Halia Wavaria*, fig. 149).	Sept. to April.	May to Aug.	Pale-green caterpillars feed upon leaves of Gooseberries and Currants, and often destroy them. Hand picking, or spraying bushes early with strong nicotine or quassia solutions.
Vapourer Moth (*Orgyia antiqua*, fig. 150).	Oct. to April.	May to Oct.	Hairy caterpillars feed upon leaves of Pears, Cherries, Roses, &c. Spray with nicotine, arsenate, and other washes, except for fruit trees. Shake caterpillars on to cloth and crush. Hoe frequently in winter and spring.
Vine Louse (*Phylloxera vastatrix*, fig. 151).	Various.	Various.	This pest attacks roots and leaves of Vines sometimes, and does much damage. Bisulphide of carbon in soil is recommended. Diseased leaves should be burned. Soil should be kept stirred.
Vine Scale (*Pulvinaria Vitis*).	—	Jan. to Dec.	Nicotine washes and fumigation. Caustic wash when Vines are dormant.
Wasps.	Sept. to May.	May to Sept.	Attack all kinds of ripe fruits. Trap with sweet solutions, and plug nest holes up at night with gunpowder, vaporite, carbon disulphide, &c.
Winter Moth (*Cheimatobia brumata*, fig. 144); and the	July to Oct.	Oct. to June.	Wingless females crawl up stems of Apples, Pears, Plums, Cherries, &c., from Oct. to Dec., and lay eggs. The caterpillars devour leaves and flowers in April and May. Grease-band in Oct. and onwards, but dig or hoe well from June to Oct. to bring up pupæ for birds.
Winter Moth, Great (*Hybernia defoliaria*). *See* fig. 122.	,, ,,	,, ,,	
Wireworms *or* Click Beetles (*Elater* or *Agriotes lineatus*, *E. obscurus*, *E. sputator*, fig. 146).	Aug. to Mar.	April to July.	The larvæ or wireworms infest many soils, especially grassland, and attack roots of all kinds of plants, and live from three to five years. Deep cultivation and hoeing to encourage birds. Also trap with potatoes, carrots, beet, turnips, &c.

INSECT PESTS OF FRUITS, FLOWERS, AND VEGETABLES (*Cont.*)

Name of Pest.	Resting Period (Pupa Stage).	Destructive Period (Caterpillar and Perfect Insect Stage).	Plants Attacked and Remedies.
Wœberian Tortrix (*Semasia Wœberana*, fig. 153).	Winter.	Spring to Autumn.	Fruit trees, generally beneath the bark, producing cankerous wounds. Winter washes if trees are not badly injured. Otherwise cut down.
Wood Leopard Moth (*Zeuzera Æsculi*).	—	—	Caterpillars burrow in stems of fruit and other trees, and live one to two years. Remedies as for Goat Moth.
Wood Lice (*Armadilla vulgaris*, &c., fig. 147).	—	Jan. to Dec.	Eat tender shoots of Maidenhair and other Ferns, destroy flowers, &c. Trap with potatoes, carrots, turnip, &c., or mix phosphorus paste and bran, and strew in runs; afterwards sweep up dead bodies.
Woolly Aphis. *See* American Blight.			
Yellow Aphis (*Siphonophora lutea*).	—	Jan. to Dec.	Attacks flowers of Orchids at all times. Careful fumigation and vaporizing.
Yellow-tail Moth (*Porthesia auriflua*).	Oct. to Mar.	April to Sept.	Black humpy larvæ feed on Apple and other fruit trees. Spray with nicotine or quassia, and cultivate soil in dormant season.
Yellow-underwing Moth (*Triphœna pronuba*, fig. 145).	Oct. to Mar.	April to Sept.	Caterpillars eat leaves of vegetable crops. Remedies as for Cabbage Butterfly.

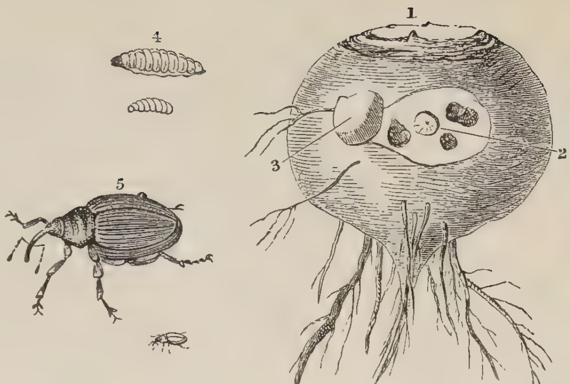


Fig. 143.—Turnip Gall Weevil (*Ceutorhynchus pleurostigma*)

1, Turnip injured by the Turnip Gall Weevil. 2, Excrescences or Galls; 3, ditto, opened. 4, Grubs (nat. size and magnified) found in them. 5, Weevil (nat. size and magnified)

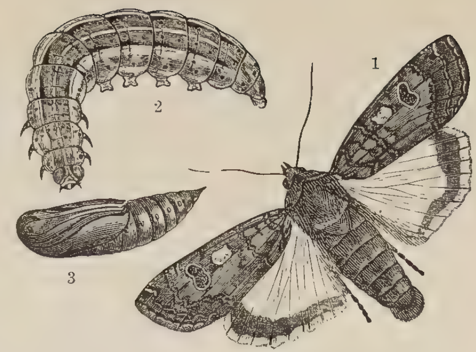


Fig. 145.—Great Yellow-underwing Moth (*Triphæna pronuba*)

1, Moth. 2, Caterpillar. 3, Chrysalis.

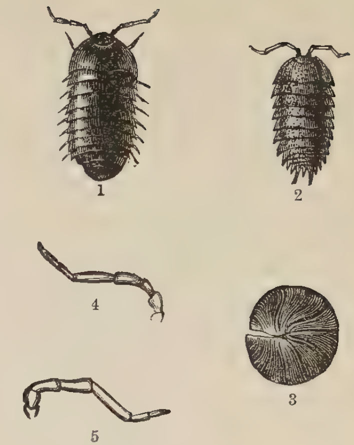


Fig. 147.—Wood Lice

1, *Porcellio scaber* (nat. size). 2, *Armadilla vulgaris* (natural size); 3, Insect (rolled up). 4, Antenna of *Porcellio scaber*; 5, ditto of *Armadilla vulgaris.*

Fig. 144.—Winter Moth (*Cheimatobia brumata*)

A, Male Moth. B, Female. C, C, Caterpillar (nat. size).

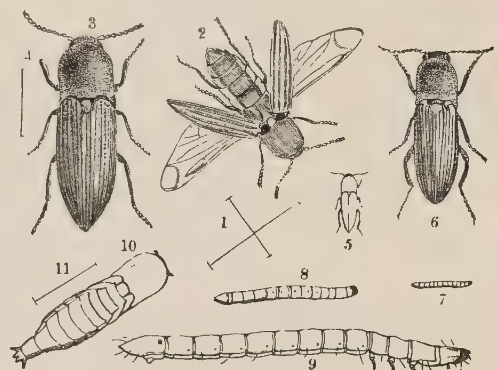


Fig. 146.—Wireworms

1 and 2, *Elater lineatus*; 3 and 4, *E. obscurus*; 5 and 6, *E. sputator* (nat. size and magnified). 7, Larva of *E. sputator*. 8 and 9, Larva of *E. lineatus* (nat. size and magnified). 10, Pupa of Wireworm, the natural length being shown by 11.

Fig. 148.—Thrips

1 to 4, *Thrips cerealium*; 5 to 8, *T. minutissimum* (nat. size and magnified).

Fig. 149.—V Moth (*Halia Wavaria*)

(natural size.)

Fig. 150.—Vapourer Moth (*Orgyia antiqua*)

1, Male. 2, Female. 3, Caterpillar.

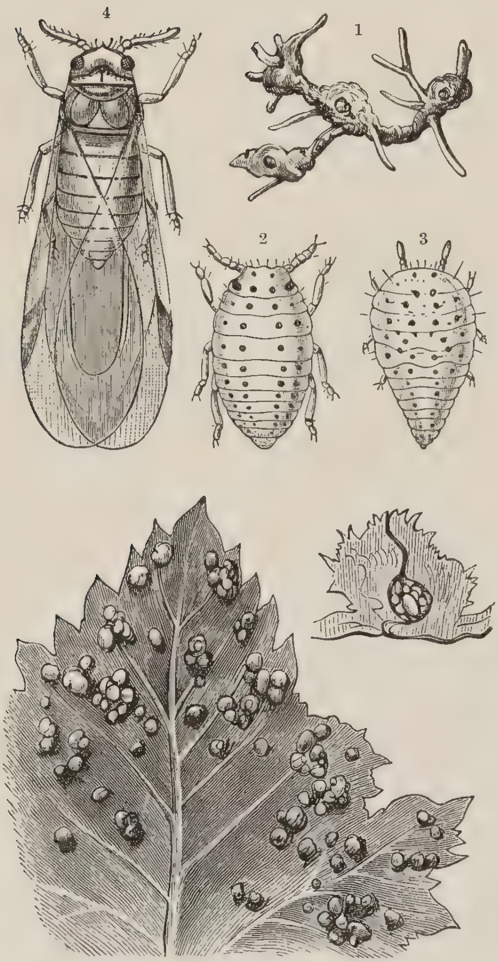


Fig. 151.—Vine Louse (*Phylloxera vastatrix*)

1, Root galls. 2 and 3, Forms of larva. 4, Winged female. 5, Portion of diseased leaf. 6, Enlarged section of excrescence on leaf.

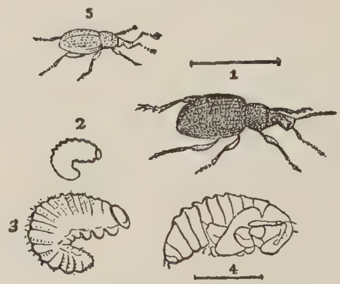


Fig. 152.—Black or Vine Weevil (*Otiorhynchus sulcatus*)

1, Weevil. 2, 3, Larva (nat. size and magnified). 4, Pupa. 5, *O. picipes*.

Fig. 153.—Wœberian Tortrix (*Semasia Wœberana*)

SECTION VII

Garden Friends

Although the gardener may look upon the great majority of insects as enemies, he must not conclude that there are no friends of his in the insect world. There are several, and it may be well to put them on record here.

In the first place the honey bee (*Apis mellifica*) does an enormous amount of good to the fruit-grower by fertilizing the pistils in the flowers of his Apple, Pear, Plum, Cherry and other fruit crops, thus ensuring a bounteous harvest, if the spring frosts have not interfered with the process of fertilization at a critical period. Whenever the fruit-grower can manage to have a few hives of bees in his gardens he will find it advantageous from a commercial point of view, and apart from the quantities of honey he may take from the hives for his own use or for sale. Bees, of course, are not only valuable for securing the fertilization of fruit trees and bushes of all kinds, but they perform similar good offices for almost every flowering plant. In a lesser degree the Humble Bees (*Bombus terrestris* and *B. lucorum*) also do good work in fertilizing flowers, but they are often charged with taking a short cut to obtain the nectar by piercing the base of the flowers of Broad Beans and Runner Beans, instead of entering by the mouth of the blossoms and thus secure the deposition of the pollen from their bodies on to the stigmas.

Fig. 154.—Ladybirds

1, Eggs, natural size, on a leaf. 2, Egg magnified. 3, Larva, with the line 4 showing natural size. 5 and 6, Pupæ. 7, *Coccinella bipunctata*. 8, *C. dispar*. 9, *C. septempunctata*.

Ladybirds.—There are over twenty species of these known in Britain, but two especially are very common in gardens, viz. *Coccinella* (or *Adalia*) *bipunctata* and *C. septempunctata*. The first-named (fig. 154, 7), is black with scarlet wing cases, and two conspicuous black spots; the second (*C. septempunctata*) is larger (fig. 154, 9) and has seven black spots on the

wing cases. Another species (*C. dispar*) is shown at 8, fig. 154. The larvæ or maggots of these Ladybirds, shown at 3, fig. 154, are slate-coloured and yellowish, and remind one of miniature alligators in appearance. It is these larvæ that feed largely on aphides, and thus help the gardener by suppressing them. The maggots and ladybirds therefore

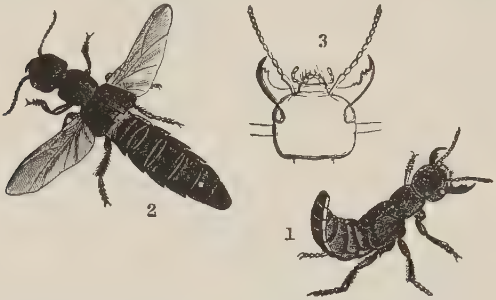


Fig. 155.—Devil's Coach Horse, or Fetid Rove Beetle (*Ocypus olens*)

1, Larva. 2, Full-grown beetle on the wing. 3, Head enlarged, showing the powerful jaws.

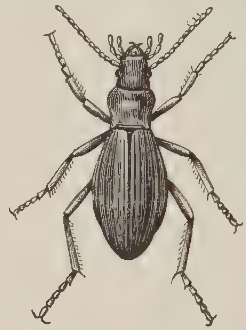


Fig. 156.—Violet Ground Beetle (*Carabus violaceus*)

should never be destroyed in gardens, and all children should be instructed as to their value.

The Devil's Coach Horse.—This is also known as the Fetid Rove Beetle (*Ocypus olens*). It has a long, narrow, deep-black body, and preys upon insects with great energy, and will soon tear an earwig to pieces. The larvæ also feed upon insect pests. During the month of May the insect is in the pupa or chrysalis state, but is very frequently met with in autumn. Fig. 155 shows the full-grown beetle and the larval stage, and the enlarged head shows the powerful jaws.

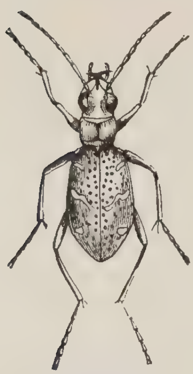


Fig. 157.—Tiger Beetle (*Cicindela sylvatica*)

The Violet Ground Beetle (fig. 156) is known as *Carabus violaceus.* It is an insect-eating beetle often found under stones and clods of earth, and is very often killed by those who are ignorant of its garden value. It has a violet-black body and rather coarsely granulated wing cases, and should be readily recognized by all cultivators as a friend.

The Tiger Beetle (*Cicindela sylvatica*), shown in fig. 157, is a black beetle with a violet under surface, and is very active in search of prey. The common Tiger Beetle (*C. campestris*) inhabits banks and sandy commons. It is about ½ in. long, and is green in colour with six white spots on each wing case, including the round one on the disk. The larva has a large head and a hump on its back near the tail, bearing two spines, by means of which it anchors itself in its burrow, waiting for its prey.

Other kinds of insect-eating beetles are those known under the names of *Pterostichus madidus* and *P. cupreus,* often called Sun Beetles, owing

(11

PERENNIAL PHLOXES

1. Crepuscule. 2. Coquelicot. 3. Tapis Blanc.

(Three-fourths natural size)

to the activity they display in running to and fro in the sunshine in search of food. The last-named (*P. cupreus*) is about $\frac{1}{2}$ in. long, with a green, bronzy, brassy or bluish-black body, the under surface being black.

Frogs, Toads, Lizards.—These much-maligned animals must be regarded amongst the best friends of the cultivator. The Frog (*Rana temporaria*) feeds upon insects and small slugs, and will also devour beetles and fairly large insects. The Toad (*Bufo vulgaris*) will also destroy large numbers of insects, including slugs, beetles, woodlice, and even worms. The toad will only eat living things, and therefore makes sure of this condition by waiting until its victim shows signs of life. At the least movement the toad darts out its tongue and swallows its prey at a gulp, except in the case of worms, which require a little more attention. The Common Lizard (*Zootoca vivipara*) lives upon various kinds of beetles and insects that are injurious to garden plants.

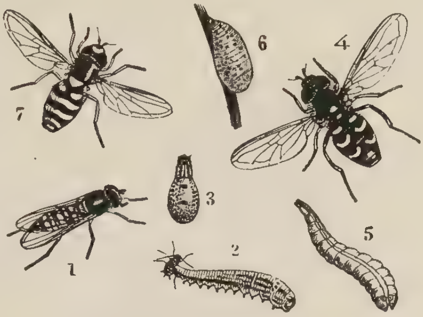


Fig. 158.—Hawkflies

1, *Scæva balteata*; 2, Larva with greenfly in its jaws; 3, Pupa. 4, *Scæva Pyrastri*; 5, Larva; 6, Pupa. 7, *Scæva Ribesii*.

Hawkflies.—These two-winged insects of the genus Scæva are very numerous from July to September, and have received their name from the fact that they hover over flowers like a hawk; but they vary the hovering by suddenly darting about. They are deadly enemies to aphides, including American Blight. The eggs of the Hawkflies are laid amongst the aphides, upon the bodies of which the young Hawkfly maggots feed voraciously, each one being capable of destroying one hundred aphides in an hour. The Hawkfly maggots are to be recognized by their relatively large, fleshy, and thin-skinned bodies resting among the aphides or slowly crawling about. They are whitish, pale green, or yellow, and in some cases lined or streaked with orange. When fully developed the maggots assume a pear-like shape, and attach themselves by the tail to some part of a plant and then pupate. In a few days the perfect insect comes forth again to carry on the war amongst the aphides. The perfect insects and the larvæ, therefore, as shown in fig. 158, should never be destroyed, if possible, as they perform such beneficial work.

Fig. 159.—Ichneumon Fly (magnified)

Ichneumon Flies.—These are found all over the kingdom, and are chiefly engaged in destroying destructive caterpillars of various kinds. Some deposit their eggs in the caterpillars or the pupæ. The Ichneumon maggots feed upon the soft parts until the caterpillar or chrysalis is about to undergo a change. This, however, it cannot effect, owing to the injuries received, and it consequently dies. Fig. 160 shows on the left how a large

caterpillar is overpowered with the maggots of the Ichneumon Flies; while on the right a caterpillar is covered with their cocoons. Amongst the prey of these Ichneumon maggots may be mentioned the Cabbage Butterfly, the caterpillar of the Death's Head Moth, the various kinds of aphides, wire-worms, and no doubt other grubs. There are so many kinds of Ichneumon Flies, all helpful to the gardener, that it becomes a difficult problem to know them from the enemies. Fig. 159 shows an Ichneumon Fly highly magnified, and it will be observed that it bears a resemblance to the wasps and bees.

Fig. 160.—Caterpillar devoured by the Larvæ of Ichneumons, and Caterpillar covered with their Cocoons

Lacewing Flies. — These flies belong to the genus Chrysopa, and, as may be seen from fig. 161 (1), derive their name from the delicate veining of their wings. The eyes are golden green, very large and conspicuous, with two long, slender feelers on the head. The female is about $\frac{1}{2}$ in. long and larger than the male. The larvæ shown at 3 and 4, in fig. 161, are very voracious, and will devour large numbers of aphides, including American Blight, in a very short time, and will even attack caterpillars about $\frac{3}{4}$ in. long. These hairy larvæ develop from eggs that are laid singly on hair-like stalks in rows and clusters, as shown in fig. 161, at 2, these slender stalks often projecting about 1 in. from the surface of the leaves or branches to which they are attached. After the larvæ have fully developed they change into pupæ and reach the perfect-insect stage in about three weeks during the summer months. The later broods pupate during the winter months in cocoons, as shown at 5 and 6 in fig. 161, and become perfect in spring.

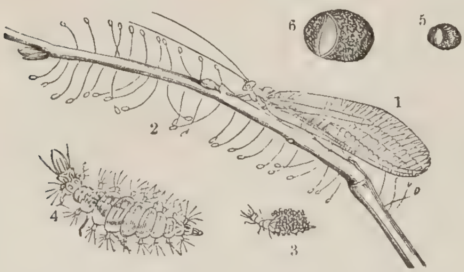


Fig. 161.—Lacewing Fly

1, *Chrysopa perla*. 2, Eggs. 3, Larva. 4, Larva magnified. 5 and 6, Cocoon (natural size and magnified).

Ear-shelled Slug.—Although most slugs are injurious to vegetation, there is one genus which provides flesh-eating slugs that will feed upon other slugs and even worms. The British Ear-shelled Slug (*Testacella*

halotidea), shown at fig. 162, is one of these. It is about 2½ in. long, deep yellow in colour, and may be recognized by a small ear-shaped shell attached to its back, just above the tail. During the daytime it nests in the soil, and is often turned up when digging; but at night-time it roves abroad in search of the common slugs and snails, and makes war upon them. A foreign species, from South Europe (*T. Maugei*), has become naturalized near Bristol, and may spread throughout the milder parts of the kingdom in time if encouraged. It has a dark-brown body with a larger shell than the native species. Cultivators should become acquainted with these friendly molluscs, and should educate their employees to take care of them.

Fig. 162.—Ear-shelled Slug (*Testacella halotidea*)

Spiders. — The true spiders, being perfectly harmless to plants, and living upon various kinds of insects, should never be destroyed by gardeners, although their webs and nests often present a very untidy appearance if allowed to remain in potting sheds, greenhouses, lofts, &c. The common garden spider, known as *Epeira diademata*, is a pretty, greyish insect beautifully speckled or spotted with white on the back of its roundish abdomen. It lives upon moths and flies of various kinds, and will easily defeat a vicious wasp in a straight fight by winding its silken cords around it.

A kind of leaping spider (*Epiblemum scenicum*), shown in fig. 163, leaps about amongst plants, and pounces upon its prey. It is grey in colour with oblique white bands on the back of the abdomen and legs.

Fig. 163.—*Epiblemum scenicum* (twice natural size)

The Weasel.—Amongst animals the weasel must be regarded as a friend of the cultivator, as it destroys rats, mice, voles, rabbits; but it also destroys poultry, and its assistance is generally regarded as a doubtful blessing.

Centipedes.—Although belonging to the same group as the Millipedes or Julus worms the Centipedes (*Geophilus subterraneus*) are not harmful to crops. On the contrary they are beneficial, inasmuch as they feed on insects, caterpillars, worms, snails, and slugs; they are active and flesh-eating insects, and should be preserved for the good they do.

From what has been said above it may be taken that although nature has sent many insects to plague and worry the cultivator of plants, it has also provided antidotes in the way of birds of all kinds, Ichneumon Flies, Ladybirds, Lacewing Flies, Tiger and other Beetles, Frogs, Toads, and Lizards, Hawkflies, Spiders, and even Slugs, by which they may be kept in check. Unfortunately, with the many poisonous washes now in use it is possible that when applying them the cultivator is slaughtering his friends as well as his enemies. Indeed he is practically not even on

speaking terms with his friends, and in many cases would not recognize them as such even if he were to see them. It would be worth while to make a special effort to cultivate colonies of Ladybirds, Ichneumon Flies, Lacewing Flies, and Hawkflies especially, as these by sheer force of numbers would readily suppress the various destructive aphides and caterpillars. When one comes to realize the wonders of the insect world, and how some kinds prey upon others, one is forcibly reminded of the truth of the couplet, that—

> "Large fleas have little fleas upon their backs to bite 'em,
> Little fleas have lesser fleas—and so *ad infinitum*".

SECTION VIII

Fungoid Diseases

Notwithstanding the enormous amount of mischief done by insect pests to the various crops grown in the open air and under glass, that caused by fungoid diseases is if anything more considerable, and necessitates a large outlay every year to keep the diseases in check. While one may by clean cultivation and attention to natural laws keep insect pests largely in check, the very best cultivators may be caught napping when a fungoid disease begins to ravage his crops. Slugs, snails, caterpillars, moths, butterflies, beetles, &c., after all are enemies that can be detected by an observant cultivator, and measures for their suppression can be taken in good time. Not so, however, with the various fungoid diseases that cause so much mischief. In the early stages these are hidden from the eye, being of microscopic proportions, and it is not until plants or fruits have been in a measure destroyed that the disease is observable. The tiny speck or blotch on a leaf or fruit to-day may develop into a large and putrid mass of vegetable tissue to-morrow, filled with thousands of spores which will be blown about by the wind, thus to carry disease and death to other plants.

The true fungi consist of a large number of stemless cryptogamic plants, the chief feature of which is that, unlike the higher Cryptogams (such as Ferns), and the flowering plants proper or Phanerogams, they lack green colouring matter or chlorophyll. Owing to this absence of green colouring matter in the tissues, fungi are unable to utilize sunlight as a source of energy and food assimilation. They cannot take in carbonic acid gas from the atmosphere, nor can they absorb nitrogen. Indeed fungi give off carbonic acid gas as a waste product. They must therefore obtain their nourishment in a form already prepared for their reception either by living plants or by dead ones. Hence there are two distinct groups of fungi: (1) those that exist on or derive their food from dead plants or organic material are known as "saprophytes", and (2) those that obtain their food from living plants are called "parasites". As a rule the parasitic fungi are most dangerous to the cultivator, because they attack his living plants in various stages, and unless checked or eradicated are likely to inflict serious losses. Intermediate between the true parasitic fungi and the true saprophytic ones comes a class that first of all causes portions of living plants to die by secretions or ferments of some kind, and then gains an entrance into the living tissues, and eventually causes their death.

According to their mode of attack the parasitic fungi are divided into two groups: (1) the epiphytic and (2) the endophytic. The latter penetrate the tissues of the plant and there develop their mycelium; the former vegetate on the surface and spread their mycelium over it.

The mycelium constitutes the typical vegetative structure of a fungus, and is of a thread-like and much-branched character. The threads of which the mycelium consists are called "hyphæ". In some forms of fungi, however, there are no threads, but separate cells, as in the Yeast Plant. The mycelium (or its hyphæ) may be one-celled, or it may be divided transversly into separate compartments, each of which may contain several nuclei from which in due course spores may develop. When the hyphæ of some fungi branch between the cells of plants, they often develop. Generally speaking the visible part of a fungus is the "fruiting" part, from which fresh spores are distributed when ripe, and are carried from one place to another by the wind and water. In such fungi as the Common Mushroom, the so-called Toadstools, the Beef-steak Fungus, and many other conspicuous plants, the spores may be readily collected if the "caps" of the fungi are placed on sheets of paper in a warm room, and may be easily seen with the naked eye. In the case of the fungi that attack our plants, however, the spores and even the entire fungus pro ducing them are very minute, and require powerful microscopes to distinguish some of their special feeding or absorbing organs, called "haustoria", which penetrate the cell walls and absorb the nourishment from the cells.

It is thought that fungi originally came from the Algæ, and have undergone various changes in the process of evolution. A fungus begins life from some kind of a spore of a very simple character, quite distinct in character and structure from the seed of a flowering plant. When the spore of a fungus germinates on a suitable plant tissue it swells up by absorbing moisture and sends out a germ tube, which penetrates the host plant and as it lengthens and branches becomes the mycelium or spawn. After a time the mycelium begins to give off fresh spores, varying in form, development, numbers, &c., according to the different kinds, and known by specialists under different names. The various spores of fungi may arise from the sexual union of two distinct cells, or they may originate asexually by means of "swarm" spores. Under certain unfavourable conditions the spores of fungi may remain dormant for a considerable time, but possess the power of germinating afterwards under favourable conditions. It is the resting power of the spores of many fungi that constitutes the chief danger to the cultivator, as he never knows how many thousands of them may be sleeping in his soil. For certain pot plants, like Ferns, it is possible to sterilize small quantities of soil by pouring boiling water over it, or by roasting it in a furnace; but such operations are quite beyond the range of practicability with large quantities of soil. The nearest approach to sterilizing the soil in the open air, and preventing the spread of fungoid diseases (as well as insect pests), is to cultivate frequently and strew powdered sulphur over any areas known to be badly

infected. Sulphur seems to be the great and most reliable antidote to fungoid attack, and this fact is so well recognized that it appears in one form or another in many of the best fungicides.

Another peculiar feature about some fungi is that they exist in two or three different forms or stages, and on two or three different plants. It is now well known that the "Smut" of corn exists in one stage on Barberry bushes (Berberis), from which it passes into another stage and then becomes injurious to corn crops. A somewhat similar state of affairs exists with the Apple Rust and Pear Rust. The fungus that exists on Junipers as *Gymnosporangium clavariæforme* passes from the Junipers and infests Apples and Pears in the form known as *Rœstelia aurantiaca*, causing orange-yellow or almost crimson patches on the leaves. Farmers now know that the proximity of Barberry bushes may lead to an attack of "Smut" on their corn, and fruit-growers know that Junipers may lead to the Rust of Apple and Pear leaves.

These cases are mentioned with the object of showing that there is cause and effect with fungoid attacks as with insect attacks, and once the real cause is known it becomes easier to check the spread of the disease.

In the following table some of the chief fungoid diseases afflicting fruits and vegetables are given, so that the grower may see at a glance the enemies he has to face. Further details will be found in Vol. III, dealing with Fruit Crops, and in Vol. IV, dealing with Vegetable Crops. The principal fungoid diseases afflicting Flowering Plants are referred to in Vol. II, under the plants attacked.

FUNGOID DISEASES OF FRUIT TREES

Common and Scientific Name of Disease.	Parts Attacked and Outward Appearance.	Treatment, &c.
Apple Black Rot. *See* Quince Black Rot.		
Apple Blight (*Micrococcus amylovorus*).	Appears on bark in small spots, which enlarge and kill the twigs and branches. Flourishes also on unripe fruit.	Use caustic washes in winter, and hot Bordeaux mixture and liver of sulphur when fruits have set. Disease also attacks Pears.
Apple Brown Rot (*Sclerotinia* or *Monilia fructigena*).	Attacks all parts, but chiefly fruits, in circular lines of reddish or yellowish pustules.	Gather diseased fruits and burn.
Apple Canker (*Nectria ditissima*).	Attacks bark, and causes it to die and form cracks. Increases rapidly and prevents healing; usually follows attacks of American Blight, the spores germinating in the wounds, and producing minute red balls in spring.	Use caustic washes in winter, and methylated spirit, paraffin, &c., in summer for Blight, and wood tar for the wounds.
Apple Powdery Mildew (*Podosphæra oxyacanthæ*).	Attacks young shoots and leaves with a white powdery mildew, causing them to shrivel in time.	Spray with hot Bordeaux mixture or liver of sulphur on first appearance, and afterwards if necessary. The disease also attacks Pears, Hawthorns, Medlars, Mountain Ash.
Apple Ripe Rot (*Penicillium glaucum*).	Attacks ripening fruits, and causes them to rot.	Collect rotting fruits and burn.

FUNGOID DISEASES OF FRUIT TREES (*Cont.*)

Common and Scientific Name of Disease.	Parts Attacked and Outward Appearance.	Treatment, &c.
Apple Ripe Rot *or* Bitter Rot (*Glœosporium fructigenum*).	Appears first as brown spots, which soon bear pustules of a white or pinkish colour, turning to black. Imparts a bitter flavour to the fruit.	Grapes, Pears, and Peaches also attacked. The "rot" increases rapidly amongst stored fruit. Spray with hot Bordeaux mixture or liver of sulphur early in season, after young fruits have set, and at intervals afterwards.
Apple Rust (*Gymnosporangium clavariæforme*).	Forms scurfy bunches or cluster cups on the under surface of leaves, with orange, yellow, or crimson blotches on upper surface.	This disease grows in one stage on Junipers, and is transmitted to Apple trees in another (Rœstelia) stage. Destroy Junipers if necessary, and spray early in season with Bordeaux or liver-of-sulphur mixtures. Also attacks Quinces.
Apple Scab or Black Spot (*Fusicladium dendriticum*).	Attacks leaves, young shoots, and fruits, first as dirty greenish spots, then enlarging, and blackening, and cracking surface, and deforming leaves and fruits.	Spray with hot Bordeaux or liver-of-sulphur solutions before flowers open, and after young fruit has set. Burn badly diseased fruits, and cultivate soil with hoe.
Cherry Spot (*Fusicladium Cerasi*).	Stems, leaves, fruits.	Remedies as for Apple and Pear Spot.
Coral Spot Disease (*Nectria cinnabarina*).	Fungus appears in conspicuous bright coral-red warts on dead or dying stems of Apples, Pears, Red and Black Currants, and numerous forest trees.	All diseased shoots should be burned to prevent spores attacking healthy plants the following year.
Currant Leaf Blight (*Glœosporium ribis*).	Attacks stems and leaves in small red-purple spots in summer, becoming irregular and grey with dark-purple margins, and destroys leaves.	Spray early in season with hot Bordeaux or liver-of-sulphur solutions at intervals.
Gooseberry "Die Back" (*Botrytis cinerea* or *Sclerotinia Fuckeliana*).	Attacks all parts of Gooseberries, and kills them in a short time; the leaves first of all turn yellow, then shrivel and die. Very prevalent.	No remedy known beyond grubbing up and burning affected plants. Cultivate soil well, and dust heavily with powdered sulphur if fresh Gooseberries are to be planted.
Gooseberry Mildew (American) (*Sphærotheca Mors-Uvæ*).	Attacks young shoots and leaves in early summer in form of white mildew, and may spread to fruits. In autumn and winter brown felt-like patches with black dots on shoots indicate the disease.	Prevalent in parts of Kent and other places. Spray with liver-of-sulphur (1 lb. to 32 gal. water) recommended, but apparently useless; burn prunings in winter.
Gooseberry Mildew (European) (*Microsphæra grossulariæ*).	Forms white powdery mildew on leaves in early summer, but is rarely harmful.	The best remedy is plenty of air and light; otherwise spray with hot Bordeaux mixture or liver of sulphur.
Grape, False, *or* Downy Mildew (*Plasmopara viticola*).	Appears as white patches on the under surface of leaves, and sometimes on stems and fruits.	Remedies as for Grape Vine Powdery Mildew below.
Grape Vine Anthracnose *or* Bird's-eye Rot (*Phoma* [*Sphaceloma*] *ampelinum*).	Mycelium of fungus penetrates leaves, green bark, and fruit, and kills tissues. Small grey spots at first, becoming sharply defined with dark-brown edges, resembling birds' eyes.	Spray with hot Bordeaux or liver-of-sulphur solutions when first noticed, and at intervals if necessary. In winter wash stems with caustic solution.
Grape Vine Brown Mildew (*Sclerotinia Fuckeliana*).	Attacks leaves and fruits in brown patches.	Remedies as for mildew below.

FUNGOID DISEASES OF FRUIT TREES (*Cont.*)

Common and Scientific Name of Disease.	Parts Attacked and Outward Appearance.	Treatment, &c.
Grape Vine Powdery Mildew (*Uncinula spiralis*).	The mycelium attacks the epidermal cells of leaves and young fruits, and forms white spots, which after a time become brown withered spots. The leaves wither, but the untouched parts of fruits grow, and eventually burst and shrivel.	Sulphur vaporized in the houses is the best recognized remedy. The mildew may also be killed by applying forcibly fine sprays of hot liver-of-sulphur solution early in season.
Grape Vine, White Rot (*Coniothyrium diplodiella*).	Sometimes attacks fruits, causing them to brown and shrivel, and later on assume a dull silvery appearance with minute white pimples—the fruit of the fungus.	Best remedy is to remove and burn diseased bunches of fruit, and vaporize sulphur as for ordinary Vine Mildew.
Melon "Nuile" (*Scolecotrichum melopthorum*).	Attacks fruits and destroys tissue.	Dust freely with powdered sulphur.
Peach Black Spot (*Cladosporium carpophilum*).	The mycelium runs over surface of leaves and fruit, causing pale spots, which become confluent, and sometimes cause fruits to crack.	Spray early in season with hot Bordeaux or liver-of-sulphur mixtures. Also attacks Plums and Cherries.
Peach Brown Rot (*Monilia fructigena*).	This is the same as the Apple, Cherry, and Plum Rot.	Remedies as for Apple Brown Rot.
Peach Leaf Curl (*Exoascus deformans*).	Leaves curl or pucker, and fall. The mycelium rests in tissues of leaves, flowers, and shoots, and attacks leaves in early stages.	Spray with hot Bordeaux or liver-of-sulphur mixtures, and collect and burn as many diseased leaves as possible, and also diseased fruits. Strew powdered sulphur over freshly turned soil.
Peach Mildew (*Sphærotheca pannosa*).	The mycelium forms a thin white coating on leaves and fruit, which become more or less deformed.	Spray with hot liver-of-sulphur solution, or dust with sulphur before fruits set.
Pear Leaf Blight (*Entomosporium maculatum*).	Leaves, stems, and fruits. The spores hibernate in depressions in the bark, and pustules appear on young leaves early in spring, causing them to drop. Dark spots appear on fruits, which become hard and corky and cracked.	Wash stems with hot caustic soda in winter, and spray with hot Bordeaux or liver-of-sulphur solutions as soon as leaves appear in spring. The Quince is attacked by same disease.
Pear Leaf Fungus (*Gymnosporangium clavariæforme*).	Attacks leaves of Pears and Junipers.	Remedies as for Pear Spot.
Pear Scab *or* Spot (*Fusicladium pyrinum*).	Causes brownish spots on leaves and fruits, also on bark of twigs.	Spray with hot Bordeaux or liver-of-sulphur solutions before flowers open, and after young fruits have set.
Plum and Cherry Black Knot (*Plowrightia morbosa*).	Causes crusty wart-like excrescences on twigs and branches, which become deformed and thickened into knots.	Wash well with hot caustic solutions in winter, and with hot Bordeaux mixture in spring when young leaves appear. Cut out and burn any knotted shoots. Cherries are attacked with the same disease.
Plum Leaf Blight (*Cylindrosporium Padi*).	The young leaves become spotted and perforated by holes, caused by the falling out of withered spots. Young trees soon defoliated.	Remedy as for Pear Leaf Blight above.

Fungoid Diseases of Fruit Trees (*Cont.*)

Common and Scientific Name of Disease.	Parts Attacked and Outward Appearance.	Treatment, &c.
Plum "Pockets" (*Exoascus Pruni*).	Attacks the ovaries, leaves, and shoots. Causes the fleshy part of fruit to swell, while stone remains stunted. The "pocket" plums dry up and hang till autumn.	Where the young shoots are considerably thickened and twisted, they contain mycelium, and should be cut off and burned. Spray when flower buds begin to swell, and afterwards, with hot Bordeaux mixture.
Plum Rust (*Puccinia Pruni*).	Attacks fruits of Plums, Peaches, Apricots, Nectarines, Cherries, Almonds.	Spray early with eau celeste or ammoniacal copper carbonate.
Plum "Silver-leaf" (*Stereum purpureum*).	Leaves assume a glossy leaden appearance, and trees afflicted die in a few years.	No sure remedy. Cut down in summer (not autumn), and burn at once. Dress soil with powdered sulphur before replanting.
Quince Black Rot (*Sphæropsis malorum*).	The mycelium permeates and destroys the skin of the fruits of Apples and Quinces, causing them to dry up and become mummified.	Spray with hot Bordeaux or liver-of-sulphur solutions when fruit sets, or when flowers are opening.
Raspberry Cane Rust *or* Anthracnose (*Glœosporium venetum* or *G. necator*).	Attacks stems and leaves in small reddish-purple spots, sunken in surface, and often confluent. Ripening fruit remains small and shrivels. The Blackberry is attacked with same disease.	Cut away old stems and decayed remains after fruit is picked, and burn, as they often contain the hibernating mycelium. In spring use hot dilute washes of Bordeaux mixture.
Shot-hole Fungus (*Cercospora circumscissa*).	Appears on leaves as translucent spots, which eventually become yellow patches, through which dark-coloured hair-like tufts protrude and bear spores at the tips. The diseased patches drop out later on, leaving holes in the leaf.	Peaches and Nectarines are mostly attacked, but Almonds, Cherries, Apricots also. The best remedy seems to be to spray with the self-boiling lime-sulphur-soda wash early in the season.
Strawberry Leaf Blight (*Sphærella fragariæ*).	Appears on the upper surface as small reddish spots, which rapidly enlarge, the centres withering and browning.	Pick and burn badly affected leaves. Spray with hot Bordeaux mixture in early summer, and dust sulphur freely over the soil and foliage.
Young Fruit Tree Fungus (*Eutypella Prunastri*).	Attacks young trees of Apples; also Peaches, Apricots, Cherries, and allied plants, wild and cultivated. Causes premature yellowing and fall of leaves. Afterwards elongated cracks appear on bark in dense clusters. Infection takes place in late spring and early summer.	Disease appears to be most prevalent on heavy badly tilled soils. Therefore cultivate deeply, and dress with lime or basic slag, after well-rotted stable manure has been added. Paint stems with 1 lb. of powdered quicklime mixed with 5 gal. of soft soap reduced to consistency of thick paint.

FUNGOID DISEASES OF VEGETABLES

Asparagus Rust (*Puccinia Asparagi*).	Attacks stems.	Diseased shoots should be collected and burned in autumn.
Bean, Kidney, Disease (*Colletotrichum Lindermuthianum*).	Chiefly attacks young pods, but also leaves and stems. Brown depressed spots, with a distinct border, appear on pods.	Destroy diseased pods by burning, and dust plants with sulphur.
Bean Rust (*Uromyces Phaseoli*).	Appears on both surfaces of leaves as small round scattered spots, brown changing to black.	Not very harmful as a rule. Spray early with liver-of-sulphur solution.

Fungoid Diseases of Vegetables (*Cont.*)

Common and Scientific Name of Disease.	Parts Attacked and Outward Appearance.	Treatment, &c.
Beet Heart Rot (*Phyllosticta tabifica* or *Sporidesmium putrefaciens*).	The outer leaves wither, followed by whitish spots with withered tissue filled up with the mycelium, which spreads inwards and attacks the roots.	Diseased plants should be taken up and burned. Mangels and Swedes are also attacked, the disease appearing from the middle of August onwards.
Cabbage Crop Black Rot (*Pseudomonas campestris*).	Bacteria attack lower leaves of Cabbages, Cauliflowers, Brussels Sprouts, Turnips, &c., and pass into the stems, which become a putrid evil-smelling mass. The veins of diseased plants show up as a black network.	Diseased plants should be taken up and burned, and the soil may be dressed with powdered sulphur.
Cabbage White Rust (*Cystopus candidus*).	Attacks the leaves, stems, and flowers of all Cabbage crops, and deforms them, covering them with a dense white flour-like mildew.	Diseased plants should be taken up and burned, and all Cruciferous weeds, like Shepherd's Purse, &c., should be suppressed by good cultivation.
Celery Blight (*Cercospora Apii*).	Causes yellowish spots on leaves, turning to brown. The mycelium grows between the cells in leaves, and sends tufts of conidiophores through stomata. Parsnips are affected by same diseases.	Spray early in season with fungicides. The Celery Leaf Blight caused by *Septoria Petroselini*, var. *Apii*, attacks leaves and stems, and may be known by small black spots.
Club Root (*Plasmodiophora brassicæ*); also known as "Anbury" and "Finger and Toe".	Attacks the roots of all Cabbage crops, including Turnips, Radishes, Swedes, and Kohl-Rabi, and causes deformed and putrid masses.	The best remedy is fresh gas lime or quicklime dug in when ground is fallow; or slaked lime or basic slag when crops are on soil, or about to be planted.
Cucumber Fruit Spot (*Cladosporium cucumerinum*).	Brown rotten depressions caused on fruits of Cucumbers and Melons.	Causes the same as leaf blotch; remedies the same, all diseased fruits being burned.
Cucumber Leaf Blotch (*Cercospora Melonis*).	Appears as small green spots on leaves, gradually increasing in size, and becoming brownish or yellow, leaves often becoming dry and shrivelled in twenty-four hours.	Chiefly caused by too high a temperature, lack of fresh air, and too much water. Remedy these conditions and burn all diseased leaves. Melons and Marrows afflicted with same disease under similar conditions.
Hop Mildew (*Sphærotheca Castagnei*).	Attacks all parts of plant, including young inflorescences, and thus destroys crop.	Spray early in season with hot Bordeaux mixture or liver of sulphur, and dust freshly turned soil freely with sulphur.
Mushroom Disease (*Hypomyces perniciosus*).	Attacks growing Mushrooms, which become an irregular mass, ultimately decaying into a putrid mass with a disagreeable pungent smell.	Diseased plants should be removed and burned when seen, and better ventilation should be given to Mushroom houses, as foul air is one of the chief causes of attack. Before spawning for a fresh crop, clean out old soil, and burn brimstone or sulphur with closed doors.
Onion Mildew (*Peronospora Schleideni*).	Covers tops of onions with a greyish mouldy velvety coat, and causes leaves to flag.	Young plants chiefly injured when grown in badly drained soil, or in low damp situations. Alter these, and spray with fungicides.
Onion Smut (*Urocystis Cepulæ*).	Attacks green leaves and subterranean scales, forming brown pustules and streaks.	Spray with liver of sulphur, or dust soil and plants with powdered sulphur early. Transplanting to fresh ground is beneficial. Badly diseased plants are best burned.

FUNGOID DISEASES OF VEGETABLES (*Cont.*)

Common and Scientific Name of Disease.	Parts Attacked and Outward Appearance.	Treatment, &c.
Potato Black Scab (*Chrysophlictis endobiotica*); also known as "Wart Disease", "Cauliflower Disease", and "Canker Fungus".	Attacks tubers and stems, and causes large irregular and mossy outgrowths.	All diseased plants and tubers should be burned. *See* article on "Potatoes", Vol. IV.
Potato Disease (*Phytophthora infestans*).	Attacks leaves, shoots, and tubers, causing them to become discoloured, brown-spotted, and rotten.	Good culture is one of the best remedies. *See* article on "Potatoes", Vol. IV. Spray as a preventive with Bordeaux mixture early in season.
Potato Leaf Curl (*Macrosporium Solani*).	Causes leaves to curl, and prevents assimilation; forms irregular blackish velvety patches.	Remedies as above for Potato Disease.
Potato Scab (*Oospora Scabies*).	Attacks young tubers, forming rough scattered patches on surface, gradually enlarging.	Avoid "scabbed" seed and half-rotted manure. Deep tillage is the best remedy, and sulphur should be freely dusted in trenches if affection is feared.
Potato Stem Rot (*Bacillus phytophthorus*).	The fungus causes the leaves to flag and turn yellow, and then to shrivel and die. The stems are discoloured, and eventually become black and rotten.	Diseased plants should be burned. Deep cultivation and wide planting, north and south, should be adopted. *See* article on "Potatoes", Vol. IV.
Potato Winter Rot (*Nectria Solani*).	Fungus appears in white tufts on stored tubers, and changes to pale pink later on to produce more spores, reducing tubers to a rotten evil-smelling mass.	Storehouse should be well ventilated, dry, and cool. Tubers should not be heaped up too much, and should be well dried before storing. A sprinkling with powdered sulphur is useful as a check.
Spinach Anthracnose *Colletotrichum Spinaceæ*).	Appears at first as moist patches on leaves, becoming minute brown pustules, and eventually grey dry areas.	Dust plants and soil freely with powdered sulphur, and cultivate deeply.
Spinach Mildew (*Peronospora effusa*).	Causes a violet-grey mildew on under surface of leaves, and yellowish blotches on upper.	Avoid waterlogged or low damp soils. Dress with slaked lime and powdered sulphur if disease appears, and cultivate deeply.
Spinach White Smut (*Entyloma Ellisi*).	Attacks leaves, and discolours them.	Dress soil and plants with powdered sulphur.
Tomato Bacterial Disease.	Attacks fruits when about size of a marble, and black blotch rapidly increases in size, eventually reducing fruit to blackish mass.	No remedy for affected fruits beyond picking and burning.
Tomato Black Rot *or* Black Stripe (*Macrosporium Solani*).	The fungus forms long blackish stripes on the stems, irregularly shaped blotches on the leaves, and black blotches on the fruits.	Best remedy is to take up and burn diseased plants.
Tomato Sleepy Disease (*Fusarium lycopersici*).	The fungus is internal, and when plants are nearly full-grown causes leaves to droop and change colour. The basal portion of stem becomes mildewed, and dull orange patches appear all over.	Take up and burn diseased plants, and freely dust soil with sulphur, after pouring boiling water over if possible.

SECTION IX

Fungicides and Insecticides

Owing to the attention that has been given to the various fungoid diseases of fruits, flowers, and vegetables of late years, a large industry has developed amongst chemists to supply remedies for checking or killing the various diseases. What has already been said about the efficacy or otherwise of insecticides at p. 167 applies with almost equal force to fungicides. The use of these has increased enormously of late years, but the various fungoid diseases seem to enjoy themselves as much as formerly on our crops. Indeed the writer has seen some of the worst cases of fungoid diseases in market gardens upon which large sums of money have been spent annually in insecticides, while other gardens, upon which not a farthing has been spent on either insecticides or fungicides, are practically immune from fungoid diseases and insect pests. Apple trees and pear trees that have been carefully sprayed for Fusicladium have had their fruits attacked quite early in the season; while in other cases, where the usual methods of cultivation were practised, but where no fungicides were used, the fruits were perfectly free from fungoid attack.

The only fungoid diseases that seem to defy all fungicides and all efforts to check or eradicate them appear to be the "Silver-leaf" of Plums and the "Die-back" of Gooseberries. Some day, perhaps, when more is known about these two terrible diseases, it may be possible to find a means of destroying them. In the meantime Victoria and Gisborne Plums are rapidly falling a prey to the "Silver-leaf" fungus (*Stereum purpureum*), while Gooseberries are being mowed down wholesale in places by the "Die-back" (*Botrytis cinerea*).

Just as many insect pests are undoubtedly due to inferior methods of cultivation, it is possible that the prevalence of many fungoid diseases is due to the same cause. The cultivator, therefore, who pays more attention to the arts of cultivation and manuring his soil, and not so much perhaps to the sciences of chemistry and entomology, will probably find his crops more free from disease of every kind. At the same time, as it is beyond the bounds of human possibility to keep fungoid diseases like that of the Potato absolutely in check, he should be prepared to suppress any sudden

outbreaks by means of fungicides that have been found more or less effectual.

Fungicides are applied either in the form of sprays or washes, as dry powders, or as vapour. So far as the sprays and washes are concerned the grower will find fungicides applied in a hot or warm state much better than in a cold one. The writer has carried out many experiments with fungicides and insecticides dissolved in *boiling* water, and has applied them in the form of a fine misty spray to outdoor crops without causing the least injury to the plants, but often destroying the pests and diseases with one good application. The reader must distinguish between applying an insecticide or fungicide boiling hot through a fine-spray nozzle, and dipping the leaves and shoots of a plant in the same solution. When the hot liquid is sent with force through a fine-spray nozzle, it impinges on the leaf or stem surface in the form of tiny globules in a mist-like spray. A good deal of heat is lost in transit, and the tiny globules are still further cooled to air temperature almost as soon as they touch the leaf surface. They have, however, retained a higher temperature than is healthy for the fungus or insect pest; hence these are usually killed outright. In spraying large areas, the only difficulty is to maintain the liquid up to a temperature of 212° F. or boiling-point, but this may be overcome by having a small portable boiler and fire attached.

The following is a list of the most effective insecticides and fungicides on the market at present:—

1. **Ammoniacal Copper Fungicide or Cupram.**—Recipe:

Copper sulphate (98 per cent)	1½ oz.
Carbonate of soda (98 per cent)	1¾ „
Ammonia solution (strongest)	12 fluid oz.
Water	12 gal.

Dissolve the copper sulphate and carbonate of soda separately, each in ½ gal. water; pour soda into copper solution and stir well. When precipitate has settled, pour off clear liquid. Wash precipitate a second time, and pour off liquid when clear. Then add liquid ammonia to precipitated copper carbonate, sufficient to dissolve it. Add water up to 10 gal., and the liquid will be ready for use. It has properties similar to those of Bordeaux Mixture. See also "Eau Celeste".

2. **Arsenate of Lead (Sugar of Lead).**—Formula (Strawson):

Acetate of lead (98 per cent)	2¾ oz.
Arsenate of soda (98 per cent)	1 „
Water to make	10 gal.

Place materials in water and stir till dissolved, when the liquid will be ready for use. One pound of treacle or soft soap may be added, if desired, to make the liquid adhere better. This mixture is now considered superior to Paris Green, as it is much lighter and does not scorch the foliage. From 1 to 2 lb. of arsenate of lead to 150 gal. water has proved effectual.

3. **Bordeaux Mixture.**—Formula:

Copper sulphate (98 per cent)	2 lb.
Lime (freshly burnt)	1 ,,
Water	10 gal.

Dissolve copper sulphate in 5 gal. water in *wooden* vessel. When lime has slaked to a fine powder, mix it with remaining 5 gal. water, and then pour into copper solution. Stir the mixture thoroughly to secure even distribution. Bordeaux mixture is regarded as one of the most useful and effective fungicides. To test the liquid add a few drops of potassium ferrocyanide (1 oz. to 10 oz. of water), and if the liquid becomes brown add more lime. To make a strong solution add an extra ½ lb. of copper sulphate to 10 gal., and to make a weak solution reduce the copper sulphate ½ lb. from formula.

4. **Carbon Bisulphide.**—This is a volatile and inflammable clear liquid, which gives off an insect-killing vapour at a low temperature. The vapour being heavier than air, it is advisable to apply the liquid at top of holes when it is desired to eradicate ground pests. For vaporizing houses about ½ pt. of liquid is sufficient for 500 cub. ft. of space, and for ground pests about 2 oz. poured into holes about 2 ft. apart is considered sufficient. It appears to be a much more costly and less efficacious method of ridding the soil of pests than turning up the soil with the spade or fork and exposing the pests to the birds.

5. **Caustic Wash or Winter Wash.**—There are several formulæ for making caustic winter washes to be applied to trees in a dormant condition. These caustic washes cleanse the bark of fruit trees and bushes from such parasitic plant growths as mosses, lichens, and algæ, thus allowing them to breathe more freely. If applied quite hot with a strong-haired brush, the eggs of many insect pests are also destroyed, such as Scale, American Blight, &c. These washes must be used in winter up to February and March, but not after the flower and leaf buds begin to open.

The following formulæ for winter washes are given:—

I. Caustic soda (98 per cent)	2 to 2½ lb.
Water	10 gal.

This is made simply by dissolving the caustic soda in the water and applying hot if possible. Care, however, must be taken of the hands and face.

II. Iron sulphate	½ lb.
Quicklime	¼ ,,
Caustic soda	2 ,,
Water	10 gal.
Paraffin (solar distillate)	5 pt.

In this formula dissolve the iron sulphate in 9 gal. of water; slake the lime in a little water and make into milk of lime by adding more water.

Then add milk of lime to the dissolved iron sulphate, passing through a hair sieve or piece of sacking to strain off gritty particles. The paraffin should then be added to the sulphate and lime, and last of all the caustic soda. The mixture should be well agitated during application, and if applied hot so much the better.

III. Self-boiling Lime-sulphur-soda Wash.—Formula:

Lime	3 lb.
Sulphur (flowers of)	3 „
Caustic soda	1 „
Soft soap	1 „
Water	10 gal.

Make the sulphur into a thin paste and pour over the lime; then boil for a quarter of an hour and keep stirred, and add the caustic soda. Continue to boil for some time, and then add dissolved soap and full quantity of water.

IV. For Apple Sucker and Plum Aphis.—Formula:

Lime	1–1½ cwt.
Waterglass	5 lb.
Salt	30–40 lb.
Water	100 gal.

Slake quicklime slowly, and then mix with water in which the salt has been dissolved. Strain through fine sacking, and add dissolved waterglass which makes wash adhere better. This wash may be used up to the time of the buds bursting.

6. **Copper Sulphate (Bluestone, Blue Vitriol, Blue Copperas).**—The purest 98-per-cent copper sulphate should be used, as cheaper brands contain impurities, chiefly iron sulphate, which may injure the foliage. One pound to 10 gal. water may be used as a winter wash.

7. **Copper Sulphate and Washing Soda (Burgundy Mixture).**—Formula:

Copper sulphate (98 per cent)	2 lb.
Washing soda (pure)	2½ lb.
Water	10 gal.

Dissolve copper sulphate in 9 gal. of water in a wooden vessel, and the washing soda in 1 gal. water. Pour the dissolved soda into the copper solution, and stir constantly. If blue litmus paper turns red in the solution add more soda while stirring, until the litmus remains blue. This mixture is found superior to Bordeaux mixture for spraying Potatoes, and is more easily prepared and applied.

8. **Eau Celeste.**—This is made by dissolving 2 lb. copper sulphate in 6 to 8 gal. of water in an earthen or wooden vessel, and then adding 1 qt. of ammonia and mixing with 50 to 60 gal. water.

Modified "Eau Celeste" is made by dissolving 4 lb. copper sulphate

in 10 to 12 gal. water, and stirring in 5 lb. of washing soda. Dissolve 1¼ lb. of soda in hot water; then add 3 pt. of ammonia, and dilute to 50 gal. of water. (See "Ammoniacal Copper Fungicide".)

9. **Hellebore Powder.**—This is prepared from the roots of *Veratrum album* and *V. viride*, and is a popular remedy against attacks of leaf-eating insects and caterpillars. The powder is a poisonous alkaloid, but loses its property by keeping. Fresh powder, therefore, should be used, and may be distributed by means of a perforated tin or through a piece of muslin. If used as a solution (which is the most economical method), 2½ lb. fresh Hellebore powder should be added to 10 gal. water, and well stirred while spraying.

10. **Hydrocyanic Acid Gas.**—This has already been referred to as a vaporizer and fumigant at p. 169.

11. **Iron Sulphate (Green Vitriol, Ferrous Sulphate).**—Formula:

Iron sulphate	40 lb.
Sulphuric acid	2 ,,
Warm water	10 gal.

Dissolve crystals of iron sulphate in the water in a wooden vessel, and add the sulphuric acid, and apply hot and fresh in winter to fruit trees. If allowed to stand for more than twenty-four hours the salt recrystallizes, and the solution is then less effectual.

12. **Paraffin Emulsion (Petroleum, Kerosene, &c.)**.—Paraffin is used in a variety of ways, and is effective in keeping off attacks of leaf-miners, like the Parsnip and Celery Fly, and others, if applied before attack. It is also useful for aphides, caterpillars, slugs, &c. The following formulæ will be found useful:—

I.	Paraffin	2 gal.
	Soft soap	½ lb.
	Boiling water	1 gal.
II.	Paraffin	1 pt.
	Soft soap	1 qt.
	Soft water	2 ,,
III.	Paraffin	1 gal.
	Soft soap	1½ lb.
	Water	10 gal.

In all cases dissolve soft soap first, and then add the paraffin and stir well. A very simple paraffin remedy is to add an eggcupful of paraffin and a handful of soft soap to a bucket of hot water, and churn well with the syringe, and apply in a fine spray over foliage.

13. **Paraffin Jelly.**—This is made by boiling 5 gal. of paraffin with 8 lb. soft soap, and adding 1 pt. of cold water, constantly stirring. When cool this becomes a jelly, and may be used at the rate of 10 lb. to 40 gal. of soft water for aphides, red-spider, &c.

14. **Paris Green (Emerald Green, French Green, Mitis Green).**—This may be had in a powdered or paste (Blundell's) form, the latter being the better. One ounce to 10 to 25 gal. water is used as an insecticide to prevent attacks of Codlin Moth, in spring, and other pests. If used too strong it will burn the leaves. This may be guarded against, however, by adding to the liquid an equal or double weight of lime in proportion to the quantity of Paris Green used. By adding a quantity of whitening to the solution it will be easy to see where the spray is distributed.

15. **Pearl Ash (Potassium Carbonate).**—This is made by boiling the ashes of plants with water and evaporating to dryness. It is deliquescent and very soluble in water. The strength varies from 40 to 85 per cent. It is used as an insecticide and fungicide, 1 lb. being sufficient for 10 gal. of water.

16. **Pyrethrum (Dalmatian Insect Powder, Persian Insect Powder).**—This powder is obtained by grinding the dried flowerheads of *Chrysanthemum coccineum* and *C. cinerariæfolium.* The powder obtained from unopened flowerheads is considered better, although more expensive. The powder is used in various ways: (i) Simply by dusting over plants affected with aphides, &c.; (ii) as a spray, 2½ lb. powder to 10 gal. hot water; (iii) as a fumigant, by sprinkling the powder over hot cinders in a greenhouse; and (iv) mixed with flour in the proportion of 1 part to 10 to 30, and dusted over the foliage.

17. **Quassia Chips.**—These are obtained from *Picræna excelsa.* They should be boiled for two or three hours to extract the bitter principle. An excellent all-round insecticide is made from 1 lb. quassia chips, 1 lb. soft soap, and 10 gal. water. The quassia chips, after boiling in a gallon or two of water, should be strained off through muslin or sacking, and mixed with the dissolved soft soap, making the whole solution up to 10 gal. Trees in fruit, Cucumbers, &c., should not be sprayed with quassia solution, as it imparts a bitter flavour.

18. **Quicklime** applied in the form of a powder is a good remedy against slugs and snails, and is also a useful soil constituent. In a slaked form lime is also useful, but two or three applications in succession are needed to kill slugs and snails. It is used with such fungicides and insecticides as Bordeaux Mixture, Paris Green, &c.

19. **Sodium Cyanide.**—This is used in connection with hydrocyanic acid gas for vaporizing greenhouses, as stated above, p. 169.

20. **Soft Soap** (also known as **Whale-oil Soap, Train-oil Soap, Fish-oil Soap, and Potash Soap).**—This is one of the cheapest, simplest, and at the same time most effective insecticides used for horticultural purposes. Good samples should be free from resin and contain not less than 8 per cent of potash. It dissolves readily in water, and 1 lb. to 4 gal. serves to kill aphides, mealy bug, scale, red-spider, &c. Soft soap is mixed with various other insecticides and fungicides, as may be seen from the formulæ given above.

21. **Sulphide of Potassium or Liver of Sulphur.**—This has become

popular as a fungicide. The sulphide is best kept in well-stoppered bottles, as it decomposes quickly when exposed to the air. For indoor plants 1 oz. to 5 gal. water is sufficient, but for outdoor plants 1 oz. to 3 gal. water is not too strong. A little whitening may be added to show where the spray falls. It discolours paint and woodwork. By adding a little soft soap to the fluid it adheres to the foliage better, and if a fine sprayer is used may be applied hot.

22. **Tobacco.**—This has always supplied an excellent insecticide to gardeners in the form of washes, fumigants, and vaporizers, the active principle of which is nicotine. It may be used in the form of powder, like Hellebore, or as a wash when steeped in hot water, or in a concentrated form in cakes and liquid. The waste ends of cigars, cigarettes, and tobacco from pipes may be preserved to make a cheap and effective insecticide. Three pounds of tobacco, steeped in boiling water and allowed to cool for six hours, will make 10 gal. of insecticide, which will be improved by the addition of ½ lb. of soft soap.

23. **Winter Washes of Lime and Sulphur.**—The formulæ for these have been given under Caustic Wash on p. 213.

24. **Woburn Wash.**—This is made as follows:—

Sulphate of copper (blue vitriol) or sulphate of iron (copperas)	1½ lb.
Quicklime	6 oz.
Paraffin	5 pints
Caustic soda	2 lb.
Water	9¼ gal.

Dissolve the sulphate of iron or copper in water by suspending in a bag a few hours in advance. Put the lime in a jar with water not quite enough to cover it. When the sulphate is dissolved and the lime slaked, add a little more water to make the latter into a milk, and then pour in the sulphate solution. Add the paraffin and churn the mixture with syringe to produce an emulsion. Then add the caustic soda, which if in powder should be broken up and dissolved separately before use. The whole wash should be well mixed, and may be applied in the form of a fine spray, but care should be taken not to let it drip on the ground or crops beneath. This wash may be used for most of the pests infesting the bark and shoots of fruit trees during the autumn and winter.

Horticultural sundriesmen supply numerous brands of patent insecticides and fungicides, such as cyllin, lysol, sodalin, VI and VII fluid, H. Emulsion, &c., and many cultivators often find it more convenient to purchase these in a state fit for immediate use, rather than go to the trouble of compounding their own solutions.

SECTION X

Glasshouse Building

These notes are intended for the man who, starting in a small way, finds it necessary to study the expenditure of every penny. Our large horticultural builders can probably put up a large range of houses at a price very little higher than the grower can do it for himself; but when it comes to one or two houses an appreciable saving can be made by doing the work oneself, and if the builder is a handy man the results will bear comparison with the professional work. All the timber can be obtained ready prepared, and the ventilators and louvre boxes can be got any size the grower likes. The most difficult part of the work is getting a good start.

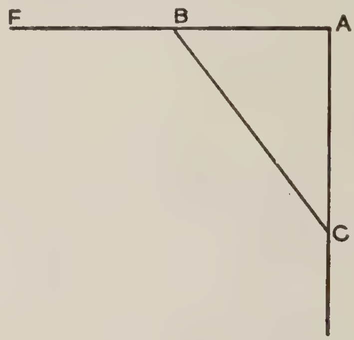


Fig. 164

Houses are best built running north and south for all except the earliest work, when lean-to's facing south are best. A start is made by laying out the footings. A good long garden line is wanted for this purpose; long enough to go all round the proposed house will not be amiss. It is most important to get the corners quite square. A large square can easily be made out of two lengths of 1-in.-by-3-in. batten, or the line can be set out square as follows. Stretch the line along what will be the side of the house. Peg out the exact length of the house, inside measurement. Use pieces of stiff thick wire for the pegs, and push them in quite straight and about 18 in. deep, so that they will not be disturbed when the footings are taken out (see fig. 164). AF is the line so laid down, and A is one of the corner pegs. Measure off AB 12 ft., and put in a small thin peg. Measure off AC 16 ft., and run a pin through the line at this point. Slip the ring of the tape measure over the peg B. Now hold the tape at 20 ft., and bring the line AC to such a position that the 20-ft. mark on the tape comes right on the pin in the line AC. Then AC will be square with AF. Now the width of the house can be measured off along AC, and a long peg put in as before. The performance is repeated at the other end, F, and then the other side

GENERAL VIEW OF MR. H. O. LARSEN'S NURSERY, WALTHAM ABBEY

Nearly every house is used for growing Tomatoes

Photos. W. Duncan Tucker & Sons

VIEW OF MODERN GLASSHOUSES AT MESSRS. R. COBLEY & CO.'S NURSERY, CHESHUNT

Showing two narrow houses with high gutters between to save waste of space at top, and to economize heat

line can be laid down between the pegs so found, and the outline of the house will be complete.

Before proceeding to take out the footings it will be as well to consider the question of the walls. The simplest and the quickest to put up are wooden walls, but an efficient wooden wall will cost almost as much as concrete and will always be a trouble.

However, if wooden walls must be built, the best way to do it is to get good oak posts, and set their butts in concrete after thoroughly tarring them. As space is limited, the details of only one form of wall can be given. Brick walls can be made in 4½-in. work with 9-in. piers every 6 ft. along the outside, but for strength, durability, cheapness, and ease of erection the concrete wall takes first place, and so this is the wall chosen for description.

For this work a quantity of thick plank and some 3-in.-by-2-in. quartering will be required. The planks must not be thinner than 1¼ in., and 1½ in. will be better, though the thinner size will do well enough if it is well supported. This planking will by no means be wasted, as it can be used after to make part of a shed, frames, or may simply be kept for wheeling on till wanted for building again. Enough planking should be got for about a day and a half's work and to make a platform about 12 ft. square to mix concrete on. For two men and a boy this would mean about 1400 ft. run of 1¼-in.-by-7-in. plank, and about 400 ft. run of 2-in.-by-4-in. scantling. The quantity would vary a little, according to the size of the house. The above quantities were used on a house 140 ft. long, and have since helped to build several more.

A 4-in. wall will be quite thick enough for any ordinary height of greenhouse wall; a lean-to wall would have to be thicker.

To return to the footings. The four pegs are now in position, marking the corners of the inside of the house. Lay down the line 6 in. inside these pegs, and cut all round with a sharp spade. Shift the line outside the pegs 18 in. away from the line just cut, and cut all round as before. Now dig out the trench so marked out, one spit deep, putting the earth on the inner side of the line for use on the borders, or else far enough away from the outside to allow a barrow to be wheeled along between. Stretch lines tightly between the four corner pegs, which should have been left undisturbed, and peg the line down at intervals to make sure it will not get moved. The 4-in.-by-2-in. scantling is now cut into convenient lengths for posts, say 4 ft. for a 2-ft.-by-6-in. wall, and a chisel point is made at one end, making the cuts on the 4-in. side of the wood only. A post is now set up in each corner just so far inside the lines as to allow the planks to be used for the concreting to be set up on edge between the line and the post both ways. Get the posts perfectly upright with a plumb-line, and fix them so by means of two stays made of slating batten driven into the ground behind each post, and nailed to it near the top so as to hold it firm in two directions (see fig. 165). The simplest way to get all the posts the right distance from the line is to make a plumb-board like fig. 166. The

board is made exactly the width of the wall, plus twice the thickness of the planking to be used for the concreting: in the case of a 4-in. wall and $1\frac{1}{4}$-in. plank this will be $6\frac{1}{2}$ in. At one bottom corner, A, cut out a little square piece the thickness of the planking, $1\frac{1}{4}$ in. Now if the plumb-board is set up with the point B, as in figure 166, touching the line, the wider part of the board will overhang the line by the correct amount, and if the posts are driven in touching this edge they must all come right. When cutting out the posts it must be remembered that they must be made long enough to allow for the height of the wall at its highest point, plus the depth of the footings and 4 or 5 in. to go into the ground, and about 6 in. extra, so that if the wall is to be say 2 ft. 6 in. high, the posts must be at least 4 ft. high, and if the ground slopes much across the house, they had better be higher by the amount of the slope, so that they can be used for both walls.

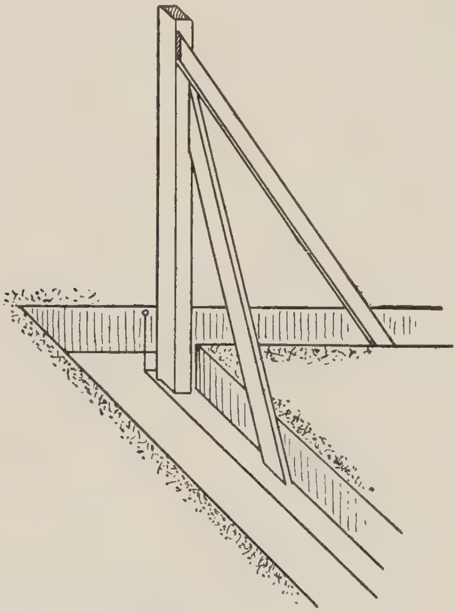


Fig. 165.—Corner Post fixed with Stays

Fig. 166.—Plumb-board

This point must now be considered. A greenhouse should have a fall of 6 in. in the 100 ft. This will allow the gutters and pipes to be fixed with the least amount of trouble. Probably the ground will have more natural slope than this. The wall is to be 2 ft. 6 in. high, so measure off that height on the post which is in the lowest corner of the site. This can be judged near enough by the eye. At this height nail on a small crosspiece square with the post. About 6 ft. off put up another crosspiece dead level with the top of the first one and in a line with the footings. Now sight along the tops of these two crosspieces, and mark off on the post in the farther corner of the trench where the eye strikes it. This point is level with the 2-ft.-6-in. mark on the first corner post. Mark off on the farther post a height of 2 ft. 6 in., as on the first, and see what the difference is

between the measured mark and the sighted mark. A rise of 6 in. per 100 feet is wanted, so that, supposing the house is to be 100 ft. long, the measured mark should come 6 in. or more above the sighted mark. Suppose, for the sake of illustration, it comes 9 in. above; this shows that the ground has a natural rise of 9 in. per 100 feet. Now that the rise of the ground is ascertained, the building may be proceeded with. Take the plumb-board (fig. 166), and against the line as already described put up a row of posts, 5 ft. apart, all the way up the line, and fix them perfectly upright with a batten stay driven into the ground on the inside of the house, and nailed near the top of the post. When these are all upright, stand the plumb-board up against each one, and drive in another post on the opposite side, the plumb-board being thus used to give the right distance between the posts. At the same time join the tops of the posts together with a short piece of slating batten; one screw to each post will hold it well. There is now a double line of posts all up the trench, perfectly upright, the right distance apart to take the boards and the concrete, and tied together at the top with the batten to keep them from spreading when the concrete is put in between the boards. The posts are carried round the ends of the house at the same time, and a glance at fig. 168 will show the arrangement of the posts at the corners.

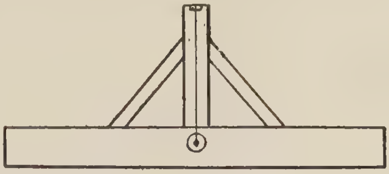


Fig. 167.—Plumb-level

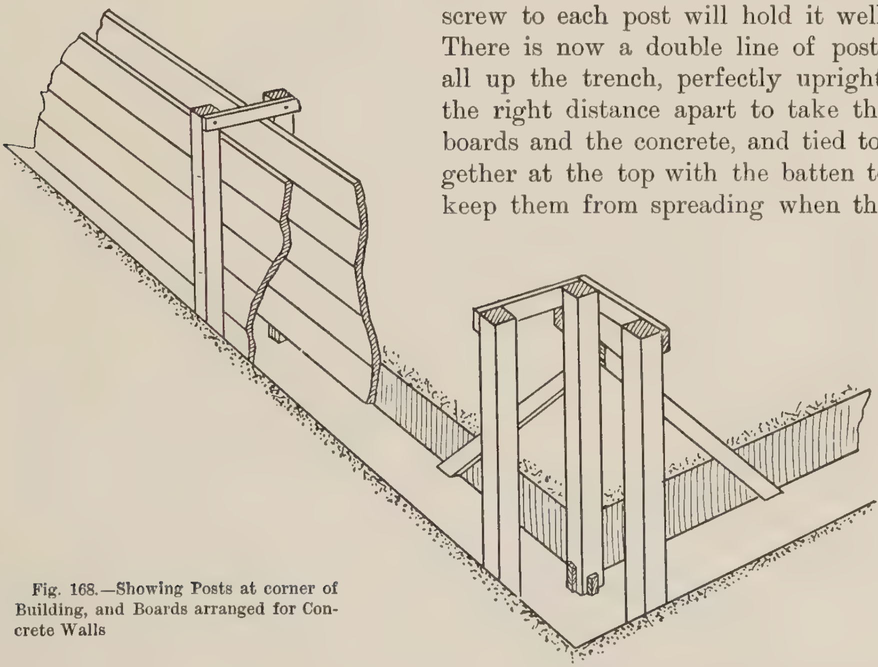
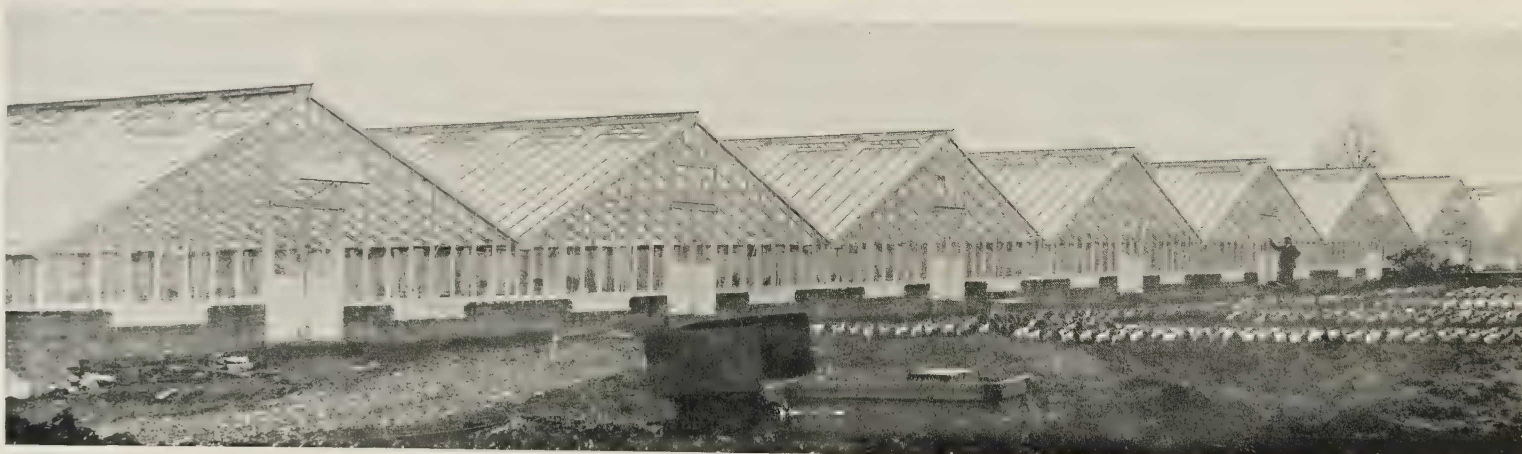


Fig. 168.—Showing Posts at corner of Building, and Boards arranged for Concrete Walls

Prepare a number of little pegs about 15 in. long out of 1-in.-square batten, and point their ends; one to every post will be wanted, and two to the corner posts. Get a contractor's level, which is a piece of board about

6 ft. long, with its edges planed parallel and a level set in one edge correctly. The plumb-level shown in fig. 167 is a very simple thing to make, and will do the work quite as well as the level just described. Whichever is used it must be set to the rise of the house—in this case 9 in. to the 100 ft. This is done as follows: Place the level on a perfectly level table or bench. Now raise one end of the level till it has a rise of 9 in. per 100 ft. For a 6-ft. level this will be almost exactly $\frac{1}{2}$ in.—$\frac{54}{100}$ to be exact. Mark on the level where the bubble comes to, or on the plumb-level where the plumb-line swings to, and use this mark to work to instead of the centre mark. Drive a peg into the ground at the bottom of the lowest inside corner post till it is only about $2\frac{1}{2}$ to 3 in. out of the ground. Go to the next post and drive in another in a similar position, but while it is still too far out of the ground test it with the plumb-level placed on the top of the first peg. Drive the second peg in gently, till, when the level is resting on the tops of the two pegs, the line stops at the mark on the level showing the rise of 9 in. per 100 ft. Proceed in the same way up the line of posts; but the pegs in the end of the house are set dead level. Now take a small level, or a square, and drive in a peg on the inside of each of the outside row of posts, getting it perfectly level with the corresponding peg on the inside post opposite. If there are any lumps on the ground which bring any of the pegs less than 3 in. out of the ground, the bottom of the trench must be shaved out with a shovel till the correct depth is attained. Any hollows are left as they are for the present. The planks are now put into place between the posts, the lowest ones resting on the tops of the pegs; thus, whatever height the wall, as long as the planks used are uniform in width, the top of the wall is bound to come straight and of the correct rise. The planks are kept from falling in by standing pieces of wood the width of the finished wall down between them. The planks being put up as far as they will go, the mould thus formed, starting from the doorway at one end and up the side of the house as far as the planks will reach, is ready for the concrete. Where a doorway is to come a piece of plank is put down between the boards at the correct spot, set perfectly upright with the plumb-line, and nailed in place. Make a platform of boards on a level spot near the mould for mixing concrete on. The concrete may consist of cement mixed with beach and sand, broken brick rubbish and sand, breeze, broken clinkers and sand, or, best of all, ground clinker with brick ends put in as the concrete is put in position. The proportions should be as follows: 5 parts of broken brick, clinker or beach to 2 parts of sand and 1 of cement. The clinker and brick rubbish should have all the large pieces broken up with a hammer till they are no larger than an egg. If on mixing up a small quantity there does not seem to be enough fine stuff in the mixture, a little more sand and a little less of the large stuff should be added, and the same with the beach. The theoretical perfection of concrete is material of some hard nature broken into pieces that will go through a $\frac{3}{4}$-in. sieve, enough sand to fill the interstices between these pieces, and enough cement to fill in



MODERN GLASSHOUSES

These houses are each 200 ft. long × 30 ft. wide and were erected at Waltham Cross and Cheshunt by W. Duncan Tucker & Sons

between the grains of sand. When ground clinker is used no sand is wanted, as the clinker is fine enough; and as this substance forms a very tough concrete, 8 parts of ground clinker to 1 part of cement will be a good mixture. When calculating out the quantities, allowance must be made for shrinkage. Ground clinker will occupy about one-sixth less space when mixed and put in place than it will when dry, while beach may be calculated as beach alone, the spaces between the stones taking up all the sand and cement. The shrinkage of other materials had better be ascertained by trial of a small quantity before ordering the bulk. The best way to measure the materials is to make a box of 1½ cub. ft. capacity, i.e. measuring 1 ft. 6 in. by 1 ft. by 1 ft. Nine of these boxes full makes just ½ cub. yd., and this is a handy quantity to mix up at a time. Of course, when the proportions are 1 in 8, as for the beach and broken brick, the quantity is just short of ½ yd.

If the box is treated as one part, no mistake can be made. The materials are shot in a heap on the platform and turned over twice dry to mix them. They are then spread out over the platform and water added through a fine rose, while Canterbury hoes are raked backwards and forwards through the mixture till it seems fairly wet. The mass is then turned up into a lump again, water being added whenever a dry portion shows, the lump being worked all the time with a Canterbury hoe as before. If not wet enough then, it must be turned once more. The finished product should be neither too wet, so as to be sloppy, nor too dry, so as to be solid. The concrete is wheeled to the mould and shovelled in. The first layer may be shot off the shovel with some force, so as to make it spread out beyond the boards, any space that is not so filled being filled up from outside up to the lower edge of the first board. As the work proceeds the louvre boxes are put in, well bedded in, and fixed by a couple of nails lightly driven through the boards. These louvre boxes are made with the sides projecting beyond the ends, for building into brickwork, &c., and for concrete work these projections had better have a **V** cut in them and have the concrete worked into the **V** when they are set in the wall. As the concrete rises to the top of the planks the plate ties must be put in. These are simply pieces of flat iron 1 ft. long by 1 in. by ¼ in. thick, bent at right angles, with one arm 4 in. and the other 8 in., and a ⅜-in. hole punched near the end of the longer arm. These are put in at every 10 ft., and always one at each corner or where a door post will come. They are set touching the inside boards of the mould, and the hole should be about 1½ in. above the top of the wall when the concrete is filled right up. The top of the wall is best finished off with a builder's trowel, being nicely smoothed down. The concrete should be left alone for twenty-four hours, and then the little crosspieces are unscrewed, the posts taken out till the last few feet of finished wall are reached, and the planks lifted out, scraped clean, especially along the edges, and placed in position farther along and filled with concrete as before. When putting the planks in place it is best to arrange them so that the ends all come in different

places, then where two planks meet their ends are made secure by screwing a piece of wood over the join on to the planks above and below. The joints in the top and bottom planks have to be made with a short piece of board put lengthways. When the walls are finished they should be left to harden while the woodwork is painted and prepared. All the wood can be bought ready formed, and it only requires the joints to be made, and the sash bars cut to the right length and angle, to be ready for use. When ordering, make allowance for the joints and order a few sash bars extra, for some are sure to be a little short or twisted; these are reserved for filling in the ends. The bars where the ventilators come can be shorter than the others, and are supported by the ventilator seat instead of the ridge. This plan makes a better job of the ventilators and saves a little wood into the bargain.

All houses are the better for a purlin, even if the bars are short ones and no purlin supports are used. Many houses 16 ft. wide have no purlin supports, but the facilities these offer for the supporting of shelves soon make up for the extra cost. Besides this, a house built with purlins properly supported and tied to one another

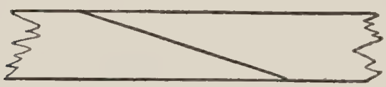


Fig. 169.—Scarf Joint

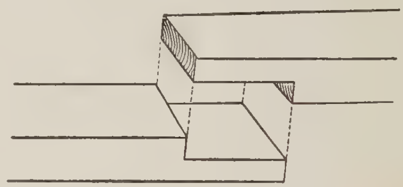


Fig. 170.—Half-lap Joint

across the house will be much stronger than the other form and will not require the iron ties running from the plate to concrete blocks in the border. These ties are nothing but a nuisance, and a poor substitute for the purlin ties at the best.

The best joint for the plate, purlin, and ridge is the scarf joint (fig. 169). It takes a little more wood than the half-lap joint (fig. 170), but is stronger and easier to make. The latter, however, is used at the corners. To get the correct angle for the ends of the bars an experiment must be made. A piece of plate is laid in position on either wall, and a small section of drip nailed in position on either side; a little piece is also cut off a length of ridge—about 2 in. will do. Two bars are then taken and carefully fitted until they will occupy their final position with the little piece of ridge between the upper ends, and fit nicely down on the plate as well. Care must be taken to keep the bars exactly the same length while fitting. The cuts can be made almost exactly right the first time if a good large-scale drawing is prepared first and the bevel gauge set to the angles so obtained.

When once the correct angles are obtained the rest is easy. A trough is made to take the finished bar and a saw-cut made through the sides of the trough at each end of the bar as in a mitre block. The uncut bars are now laid in the trough, one after the other, and the saw, guided by

the cuts in the sides of the trough, will cut every bar exactly alike. The short bars where the ventilators come have only the lower end cut like this; the upper end is cut to fit the seating.

After all the wood is cut it should be gone over and all the knots and resinous places be painted with patent knotting, then a good coat of priming should be given. As soon as dry, the second coat is given, special attention being given to the joints. The lower side of the plate should be tarred, but even if the remainder of the plate is ultimately to be tarred it should be left for a year till thoroughly seasoned; for unseasoned wood, tarred, will develop dry rot very quickly.

The end rafters are cut in the same trough as the sash bars, and care must be taken to cut them in pairs, as they only have a glass rabbet on one top edge for the roof, and one bottom edge for the ends. The best way to avoid mistakes is to set them up in pairs and mark their top ends.

In putting up the roof a start is made by putting up two end rafters, nailing them lightly at the bottom, and leaning the ends together. Holes should be bored previously for all the nails in the bars and joints, to avoid splitting the wood. Two trestles tall enough for the builder to reach the tops of the bars with ease will be required; a strong plank along the tops will enable the builder to put up several bars without shifting. A piece of ridge is now lifted up and pushed between the top ends of the end rafters and held there while an assistant supports the other end of the ridge with a couple of sash bars put in position and lightly nailed in place. The end rafters are now carefully adjusted and nailed fast. A long piece of wood is then put up and nailed to a peg driven into the ground in front of the end of the house; the other end of this piece is nailed to the side of the ridge as soon as the end bars have been got quite square with the plate. When this strut is fixed the roof will remain firm while some more bars are put up, or till the rest of the roof is finished. Two gauges, exactly the width of the glass to be used, are made out of scroll iron or hard wood, and as each bar is put up these gauges are put in where the glass will lie to keep the bars the right distance apart while the nails are being driven. Where the ventilators come a long gauge will be required, as two bars are left out till the ventilator seating is in place. These long gauges want making very carefully or trouble will be met with when the short bars go in. When the end of the first piece of ridge is reached the supporting bars are knocked away and a fresh piece of ridge is put up. The assistant holds up the free end while the builder nails the other to the first piece, and then gets down and supports the free end with two bars as before. The purlin is fixed by boring holes right through the sash bars and the purlin and driving a long wire nail right through and clinching on the inside. While the roof is being built it is as well to nail long boards right across the house, from plate to plate, to prevent any strain being thrown on the plate before the purlin is on and properly tied and supported.

I see that the setting of the plate has been omitted. This is put

on a good bed of mortar having a little cement mixed with it, spread evenly along the top of the walls, the plate being well jarred down to settle it in position. As soon as it is on it is fixed to the wall by means of the plate ties set in the wall, coach screws being used to hold it. The drip is then nailed on. In case any of the ties are a little out of the straight it is as well to sight along the wall before fixing, and see if any want letting into the plate or keeping away from it by a small piece of wood. The purlin ties are made out of gas pipe, which can be obtained very cheap secondhand; any blacksmith can work them up to shape. The lengths are all cut right, and then the ends are flattened out, bent over to fit the slope of the purlin, and a hole punched for a coach screw at each end; these are screwed down to the purlin at every 10 ft. The purlin standards may be wood, tied down to a concrete pier at the bottom and screwed to the purlin at the top, or of gas pipe set in a concrete block at the bottom and split, spread apart, and screwed to the purlin at the top. The gas pipe is the better material. If used it is a good thing to slip a 2-in. drain tile on the lower end before it is flattened, to make it grip the concrete. While the concrete is being put round the end the pipe is held up, and when the hole is full enough it is slipped down till it is bedded on the concrete. Soil is then filled in all round, and cement is made to a thick cream and poured down between the pipe and the standard. This arrangement will keep the standard from rusting where it enters the ground. I have never seen anyone else do this, but offer the idea for adoption by the man who builds to last. I always do it myself; it is very cheap and prevents all rusting through at the ground line. If iron or wooden standards are dispensed with the house must be kept from spreading by iron rods screwed to the plate and set in a concrete block in the border; these are put in every 10 ft. There is very little economy in this method, as unless the walls are very low, almost as much pipe is required as for standards, and these plate ties are always in the way.

If the house is to be heated, a stokehole must be dug at the lowest end of the house. Plenty of room must be allowed for working in front of the boiler and for a division for fuel. The space for fuel need not be very wide if a kind of bin is made of boards fitting into grooves made with pieces of batten fixed to the walls of the hole. Three feet will do nicely for this division. In front of the boiler a space equal to the length of the boiler when set, plus 1 ft. extra, should be allowed for withdrawing the cleaning rods from the flues. The walls of the stokehole are easily made with concrete. The chimney should not be skimped, but should be made 15 ft. high, and with a flue at least 1 ft. square; a larger boiler will want a flue in proportion. A 3-in. drain should be taken from the bottom of the stokehole, so that no water can collect and the pipes can be emptied at any time without trouble. If there is a good natural slope to the ground, and there is some distance to go with the drain, the job may be made less formidable by gradually bringing the drain nearer

INTERIOR VIEW OF MODERN GREENHOUSE

120 ft. long, 40 ft. wide, with hot-water pipe overhead. Erected by Messrs. W. Duncan Tucker & Sons

the surface, and then it can be carried the rest of the way at a depth of 18 in. As long as a fall of 6 in. per 100 ft. is allowed, the drain can be reduced in depth as soon as possible. The stokehole must be made deep enough for the flow pipes to be taken off the boiler easily. In this connection a lot of room may be saved if the boiler is fitted with a short bent flow socket. If more than one house is to be run from the same boiler, screw-down valves must be provided on the flows and returns in each house. All exposed pipes round the boiler and leading to the houses should be coated with asbestos cement, and the pipes from the boiler to the houses are much better boxed right in with brickwork or concrete. A serious amount of heat will be wasted unless this is done. The back rows of pipes can be slung from the plate by iron hooks fixed to the plate with a 2-in.-by-½-in. coach screw. If these hooks are made all the same length, and the proper fall has been given to the house walls, the pipes can be set with the greatest ease. For greater security it is best to have the pipe hooks bent over at the top so as to fit the plate, and thus give the coach screw assistance in bearing the weight of the pipes. The front rows of pipes are slung from the purlin standards or placed on brick or concrete piers. These are very simply made with concrete as follows: Holes about one spit deep and 1 ft. square are dug out in a line up the house, where the pipes are to come; pegs are set up in the middle of the holes and the correct rise given to them in the same way as to the pegs used when giving the rise to the walls; 2 or 3 in. of concrete is put over the bottom of the holes and then a little framework of any odd bits of rough wood is put round each peg so as to leave space for the pier to be made 5 in. square. The concrete is now filled in up to the top of the pegs and the piers will be ready as soon as they have set. When the pipes are put on the top they should be bedded in cement mortar. The pipes are put together with cement joints made as follows: The pipes are slipped into each other, then about two strands of pipe yarn are twisted up and driven into the joint with a caulking tool till the end of the joint is reached. Pipe yarn as bought consists of four strands twisted, but this is too thick to be driven in. Three strands are now twisted up and just tucked in all round the joint, leaving a little hole at the top. Make a little cup with the loose ends of yarn and pour into the space between the two rings of yarn cement mixed to a thick cream till no more can be got in. Tuck in the loose ends and drive the yarn in as far as possible. The next day the joint can be faced up with neat cement made into a stiff mortar. Nothing short of a red heat will loosen such a joint, and they will stand all ordinary pressures without leaking; a few drops may ooze through when the pipes are first filled, but this will generally stop in a short time; if not, the facing must be chipped off, and, if possible, some of the yarn scraped out and the joint refilled with cement mortar as before. Hot-water pipes can easily be cut with a sharp cold-chisel to whatever length is required. The chisel should be given a point with a rather wider

angle than is usual, and the temper should be as hard as possible to stand without chipping. The wide angle helps in this matter. A mark is made round the pipe where it is to be cut, and the pipe laid on the ground so that it is touching immediately beneath the cut. The line is now followed round with the chisel, giving light sharp taps to the tool with a hammer. As soon as the line is chipped all round, go round again, hitting a little harder, but still as sharply as possible. During the third time round the pipe will probably crack all along the mark and break off clean; if not, the process must be repeated till it does crack. The flow pipes in the house should stand 6 in. higher than the returns, and an air pipe must be fitted at the highest point in each row.

A tank for keeping the pipes supplied with water must be placed somewhere where it can be filled easily. This tank should not be too small, or when the water in the pipes gets hot the expansion will cause an overflow and a consequent shortage when the water cools again; 20 gal. will do for a small house or two, but a 30- or 40-gal. tank will not be a bit too big for say 1500 ft. of pipe. An expansion pipe must be fitted to the boiler, and should be $1\frac{1}{4}$ in. diameter for anything but a very small boiler; this pipe should rise to a height of 6 ft. above the highest point in the pipes. When setting the boiler, a good rise should be given to it. The makers will say what rise to give their special boiler, but any of the forms of saddle boiler will want a rise of $\frac{3}{4}$ in. to the foot.

With regard to water supply, for forcing, it will be necessary to have tanks in the houses, and for obtaining warm water one of the pipes should be taken through the walls. To do this a sliding collar with a joint formed with indiarubber rings must be put on to the pipes where they will pass through the walls of the tank, and this must be done before the pipes are joined together. These collars are built into the walls of the tank, and the pipe inside is thus free to move a little with the expansion and contraction due to the temperature. If this is not done the movement will crack the walls of the tank. Tank walls should be 6 in. thick, made of good concrete, and faced with sharp sand and cement in the proportions of 1 part cement to 2 parts sand. When the facing is set it should be brushed over with a wash made of neat cement, or, better still, let the walls get quite dry and then paint over, first with a solution of Castile soap, $\frac{3}{4}$ lb. to the gallon of water, allowing twenty-four hours for drying, and then with a hot solution of 2 oz. of alum to the gallon. This process can be repeated if necessary; but it is said that four coats are impervious to a head of 45 ft. of water, so that one coat should be sufficient for a greenhouse tank. When ground clinker is used for making the concrete it may be economized by making old bricks or the concrete to a batter, and as it is filled into the mould any kind of hard rubbish can be bedded in it. Long tank walls should have old lengths of gas pipe put in to strengthen them, and pieces of small pipe or iron bar should be bent round and set in the corners. Corner irons should be put in the greenhouse wall as well.

To return to the actual building of the house, some form of gearing should be fitted to the ventilators, and there are several good and cheap forms on the market; but the bottom gearing is more difficult to do cheaply, and the only thing to do is to have one worked by levers fitted to a gas pipe running in bearings screwed to the louvre framing, the movement being applied by means of a worm wheel and cog.

The glazing can be let out piecework at 2*s.* 6*d.* per 200-ft. box of glass, unless time is no object. Brass brads should be used for fixing the glass and no top putties. The lowest panes should have three brads at the bottom edge to make sure they shall not slip down. In some way or other these bottom brads work out and let the glass slip down; and the only suggestion I can make is, that the drip, freezing round brads lifts them out a little at a time till they are quite loose. The best hinge for ventilators and louvres is that supplied by Messrs. Paine, Mainwaring, & Lephard, of Worthing, whose patent it is. I am not aware of any other patent makes, and so feel at liberty to mention this form as better than the common cross garnet or the water-joint T hinges, which soon wear or rust out. The ventilators can be glazed before they are hung. Before the glazing is done a couple of wind stays should be put in at each end of the house; these are made of pieces of 1-in.-by-3-in. batten, the longer the better. These pieces of batten are carried from the under side of the top end of the rafters to the plate, as far back in the house as the battens will reach, and a screw is put through into every bar where they cross; but the glass gauge should be put in while the stays are being fixed to the bars, to make sure that they keep the right distance apart. As the end rafters are 1 in. deeper than the glass bars the stays will have to be let in; this makes all the stronger job.

Allowance must be made for carrying off the rainwater from the roof. A cheap form of gutter can be made of wood. Instead of using the usual narrow drip, 1-in.-by-3-in. batten is nailed in its place, and to the outer edge of this pieces of 1-in.-by-4-in. batten are fixed by screws placed at every foot. The joints between the ends of the pieces are made by making a saw-cut right down the middle of each end, and then when all the pieces are in position short pieces of hoop iron are driven up the cuts; when the gutter is well tarred there will be no leak. Outlets can be made into the tanks, and the waste water from the ends can be carried off into a drain.

Where it is important to save all the water it is best to take the rainwater from the end of the gutter through 2-in. gas pipe laid under the border to the first tank: then if the tanks are joined up the water will fill all at the same time. If iron guttering is preferred, the narrow drip is used and the gutter fixed to the plate under it. As soon as the glazing is finished the last coat of paint should be got on, and for inside work some special greenhouse paint should be used; it may cost a shilling a gallon more, but it will last much longer. There is also a special

greenhouse putty called "Plastine". This is double the cost of ordinary putty, but it never gets hard, and repairs can be carried out with the greatest ease; there is also less shrinkage with this, and consequently less leakage. All ironwork should be coated with iron-oxide paint.

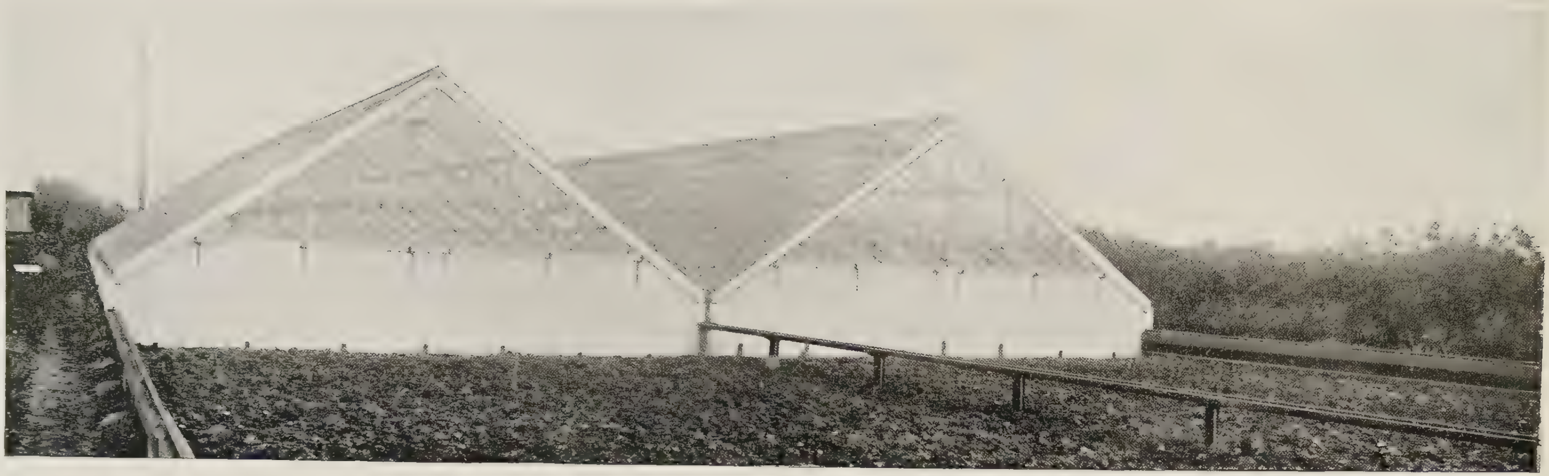
Glass can be got in all sizes, and a very usual size is 20 in. by 16 in., and 24 in. by 18 in., the panes being put in lengthways; more bars are required this way, but the house is stronger. The glass used should always be 21-oz. [W. M. B.]

Greenhouses on Rails.—About twenty years ago the idea of having movable greenhouses occurred to the Horticultural Travelling Structures Company, and many of their buildings are now to be seen in actual use by market growers in all parts of the kingdom. This company has protected and patented its structures, and are the only builders in the United Kingdom. Quite recently some American growers have had similar greenhouses built on the same principles. The system consists in having a rail at each side upon which the greenhouse rests and runs along by means of wheels when it is necessary to move it from one crop over another. The Plate shows how the rails are fixed at the sides and between two houses. The rail in the centre is of rolled steel channel iron, and rests on iron stanchions bedded in concrete, and serves the purpose of a gutter as well as a railway. The outside rails either rest on brickwork or on stanchions; in the latter case the spaces between the stanchions being filled in with creosoted boarding.

These travelling glasshouses are used chiefly for bulbs, Strawberries, and low-growing crops generally, and in cases where a rotation is required without the application of much heat for forcing purposes. In England where the houses are in use, three crops of bulbs—chiefly Narcissi—and one crop of Tomatoes, are generally produced during the year. In the Channel Islands, however, four crops of bulbs are often grown one after the other.

A modified type of glasshouse has recently been brought out by the same company. It is from 40 to 50 ft. wide, with high sides to the eaves to allow greater headroom for the crops. Such wide houses are common in the United States, where the roofs are trussed by rolled rods fitted together by forgings or screwed together in castings. This wide type of house is considered superior to the older forms although it is more expensive to erect. The Horticultural Travelling Structures Company have substituted substantial wires for the rods used in the American houses, and this reduces the cost considerably, and the new system, which has been patented, can be applied to houses 30 ft. wide as well as to those of wider dimensions.

The other photographs show some of the more generally adopted glasshouses used by market nurserymen in England. They are from designs made by Messrs. W. Duncan Tucker & Sons, of Tottenham, who not only erect them for the trade, but also supply timber already prepared to growers who prefer to erect their own greenhouses.



GREENHOUSES ON RAILS, SHOWING MOVABLE ENDS AND RAIL BETWEEN

Photos. Horticultural Travelling Structures Co.

INTERIOR OF GREENHOUSE ON RAILS, SHOWING CROP OF NARCISSUS

Overhead are strings tied up to be used for crop of Tomatoes during the summer

SECTION XI

Heating Apparatus

Market growers and nurserymen who have to erect large greenhouses for their crops do so strictly on business principles. The ornamental structures seen in private gardens and public establishments do not appeal in the least to men who have to grow plants for a living, and who erect glass structures not because they like to, but because they must. Not only must money be spent in the erection of glasshouses and frames, but a suitable temperature must be maintained in them by means of artificial heating. In the old days, before hot-water pipes came into use, glass-houses were heated by means of "flues", and in very old gardens some of these still exist. Flues consist of a passage from the furnace up and down one side, or all round, a house, and enclosed by tiles or bricks in such a way that sulphurous fumes shall not leak into the house and destroy the plants. The heat and smoke are carried along these flues, and find an exit in the chimney. The heat obtained from the flue surfaces was much or little according to the way the furnaces were fired, and excellent results were obtainable by this method of heating.

The flue system, however, is now obsolete, and no one would dream of heating a modern glass structure by it. Hot-water pipes and boilers have come to stay, and taking everything into consideration, they not only supply all the heat required, but they can be regulated by means of valves to raise or lower the temperature. Not only that, but hot-water pipes can be arranged wherever the grower wishes—either along the floor, around the walls, under or over the stages or benches, and along the roof itself if necessary. Indeed in many modern glasshouses in large market nurseries 4-in. pipes are run along the entire length of a house overhead. It is claimed for this method of heating that the air throughout the house is kept at an equable temperature, and in the event of severe frosts no danger is to be apprehended to plants inside near the glass. The installation of these pipes overhead naturally entails extra expense, but that is counterbalanced by the great advantages derived. The pipes are supported at intervals by uprights, so that there is no strain upon the roof or sash bars. Although 4-in. pipes are generally used, 3-in. and 2-in. are also employed under special circumstances.

Boilers.—Of these there are many varieties on the market—all sorts, shapes, and sizes. Some of the older types, like the "wedge", "coil", and "conical", have been driven out altogether, even from private establishments, having been superseded by the "saddle" (of various designs), the upright and horizontal "tubulars", the "Cornish" or cylinder boiler. And during recent years the "sectional" boilers largely used on the Continent and in America have begun to find a footing amongst British growers.

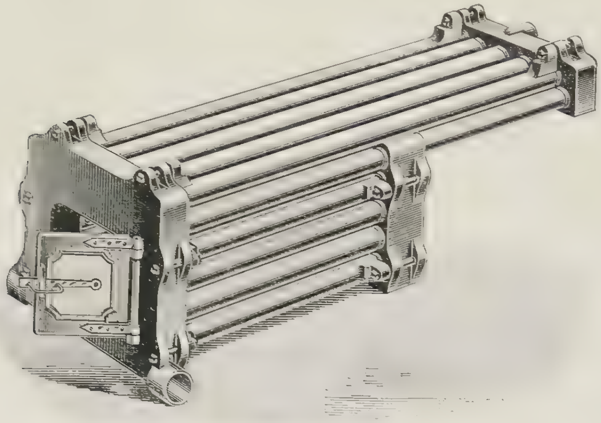


Fig. 171.—Rochford Horizontal Tubular Boiler

What the market grower and nurseryman aims at above all things is to have a boiler that will not only wear well, but will generate the greatest amount of heat at the least expense of coal or coke, or labour in stoking. In addition to this, one that can be repaired easily is a great advantage.

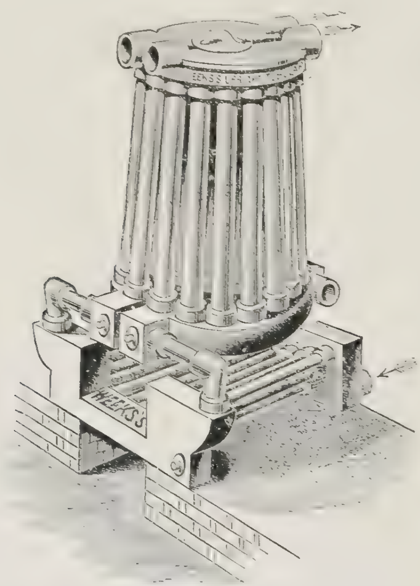


Fig. 172.—Weeks's Duplex Upright Tubular Boiler

At the present day perhaps the horizontal tubular boiler, as shown in fig. 171, is the most popular with large growers. The flues are in a direct line to the smoke shaft, a greater surface is exposed to the fire and consequently heat is generated more quickly; and in the event of a tube giving way a new one can be substituted in a very short time. A boiler of this description, 9½ ft. long, is capable of heating 2000 ft. run of 4-in. pipe, the total cost for boiler and fittings being about £20.

The duplex upright tubular boiler as shown in fig. 172, although extensively used in private places, is not so largely patronized by big market growers. This particular boiler is made in two equal parts each of which can be worked independent of the other in case of accident. As a rule the two sections are worked as

one boiler, and this gives the advantage of two flows and two returns, which can be made independent of each other if necessary.

The "saddle" boiler is still very popular amongst all classes of growers, especially amongst the "smaller" men who cannot at first, perhaps, afford to instal the dearer kinds. The plain "saddle" boiler, which has an opening right through, still does serviceable work, but whenever possible it is replaced by the type having a check or waterway end (fig. 173). There are many types of these saddle boilers on the market, one of the flued type being shown in figs. 174, 175, in elevation and section. It is known as the Gold Medal boiler, and is made of wrought iron. The heat from the fire (*b*) strikes the waterway end (*e*) before ascending into the centre flue (*c*), whence it is deflected into the flues right and left (*d*), and then goes over the top of the boiler. In the figures the ashpit is shown at *a*, the flow pipe at *h*, the return pipes at *i*, the sliding doors for cleaning out the flues at *f*, and the draw-off cocks at *g*. These are useful when it is intended to clear the water out of the boiler. At *l* the hollow space is shown round the boiler to utilize the heat given off from the surface.

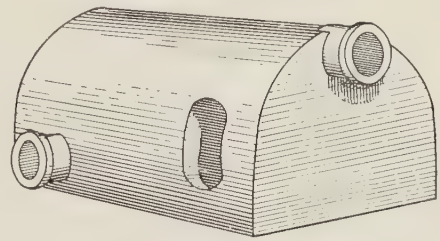


Fig. 173.—"Saddle" Boiler with Waterway End

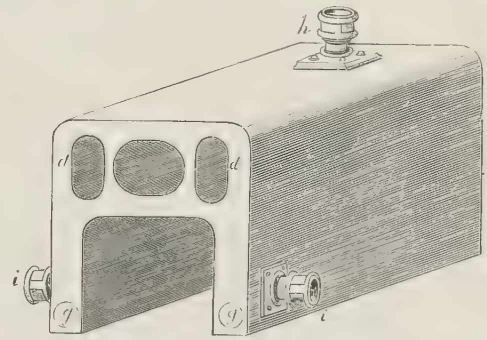


Fig. 174.—Gold Medal Boiler (elevation)

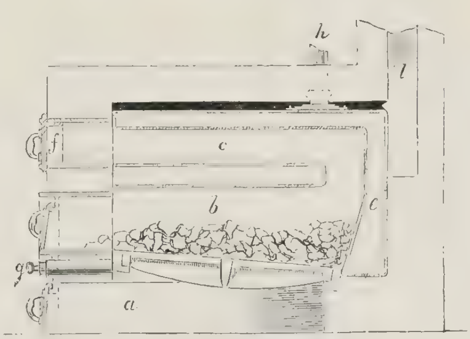


Fig. 175.—Gold Medal Boiler (longitudinal section)

In the improved Cornish or Trentham boiler, shown at fig. 176, we have a circular or cylindrical type, being a modification of the Cornish steam boiler. The boiler consists of wrought-iron cylinders welded together, and is seated on two iron chairs or supports as shown at *a a*. The front chair forms the frame for the lower and upper flue doors, shown at *b b*, by means of which the soot can be easily removed. At the bottom of the cylinder is a plug *c*, which, when unscrewed, allows the water and all accumulation of dirt in the boiler to escape when necessary. The two furnace doors are shown, one open, at *d*, while *e* is the flow pipe on top, near the back, and *f* the return pipe low down at the side towards

the front. In the Cornish or Trentham boiler a large water space is exposed to the fire, and as the heat has most force on the upper side, where there is less likelihood of matter accumulating, there is an excellent circulation of hot water through the flow into the pipes in the houses.

Sectional Boilers.—Of late years these have attracted some attention among market growers, and many are now using them. The chief advantages appear to be that a boiler can be added to if necessary if more work is required from it. Each section is independent and can be bolted on to the others or taken away. They are considered to be very economical in fuel, they are easy to stoke and keep clean, and the cost of brickwork is saved in the setting. Being made of cast iron they are less liable to rust than the wrought-iron boilers are when fixed in a damp stokehole; and in the case of a section giving way, it can be easily replaced instead of the whole boiler being rendered useless as would be the case with a wrought-iron boiler.

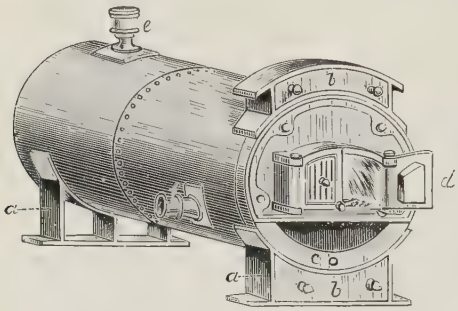


Fig. 176.—Stevens' Improved Cornish Boiler

There are several kinds of sectional boilers now on the market, one of the best known being the "Robin Hood" of Messrs. Foster & Pearson (fig. 177), of which there are several patterns. Other makes are the "Mona" and "Anglian". The illustration (fig. 178) shows a type having a Sylphon automatic regulator by means of which the draught can be regulated. Automatic regulators, however, are not recommended for damp stokeholes, as the rust soon causes the working parts to be out of repair.

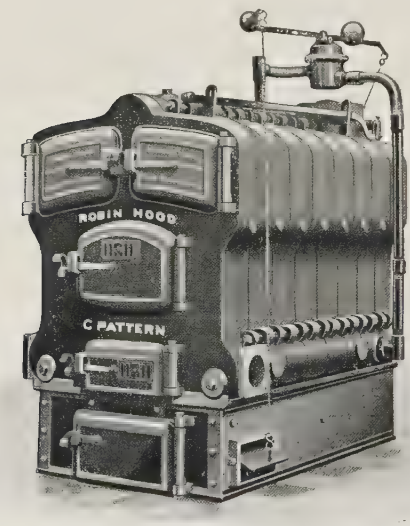


Fig. 177.—Sectional "Robin Hood" Boiler

Setting Boilers. — Generally speaking it will not pay a nurseryman or market grower either to set his own boilers or pipes or to build his own greenhouses. That is work best done by horticultural builders who make a speciality of it. And yet many growers take a pride in being able to build their own glasshouses, and to set their own boilers and pipes. Then they can blame nobody else if anything goes wrong. The

writer has had some experience in these directions, but he would not care to proclaim his work as being altogether a model of superb workmanship. At the same time it is useful for a grower, and especially one with limited means, to be able, at a pinch, to build a greenhouse, or set or repair a boiler. It sometimes happens, usually on a frosty night in the depth of winter, that a boiler springs a leak, or a pipe cracks or bursts in some place. Under these conditions it is no use waiting for the expert to arrive, while the crops are being frozen or scalded to death, and prompt measures must be taken. The old boiler may have to be taken out at

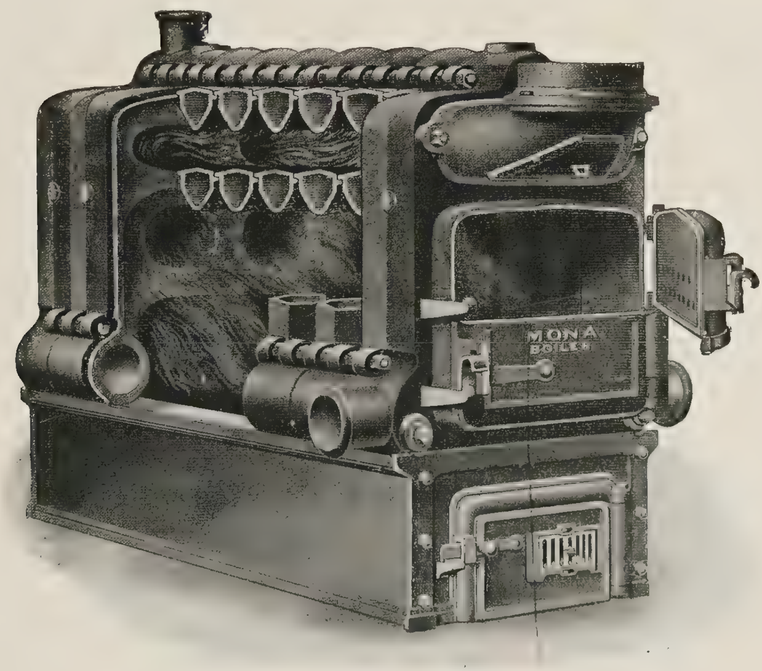


Fig. 178.—The "Mona" Boiler

once and replaced with a secondhand one on the premises, or a defective section of piping must be replaced immediately with a sound one. It is in special circumstances like these that a man who understands how to set a boiler or replace a pipe is of the greatest value. There is nothing lost therefore in acquiring a practical and theoretical knowledge of the art of heating by boiler and pipes.

Principles of Hot-water Circulation.—Every grower should know why the water from the boiler rises and flows upwards through the flow pipes and comes back again to the boiler by the return pipes. It may be possible to explain this by means of the accompanying diagram (fig. 179). Let A represent a boiler with flow pipe at B, return pipe at C, and fire at D. When heat is applied, some of the water in the boiler absorbs heat and therefore expands and becomes lighter, and requires more space.

The colder water in the return pipe C, being heavier than the heated water, rushes in at the bottom of the boiler, and thus pushes the warmer water upwards, and forces it through the flow pipe to fill the space caused by the flow of water from C to the boiler. The greater the heat applied the quicker the circulation. Now, as the heated water travels along the flow pipe B it is gradually losing its heat, and its colder particles begin to sink to the bottom. It cannot, however, return the way it came, because it is being pushed forward by the hotter water coming from the top of the boiler, which in its turn is forced up by the colder water entering the boiler by the return pipe C at the base. Thus, while the water in the pipes is gradually losing its heat, that in the

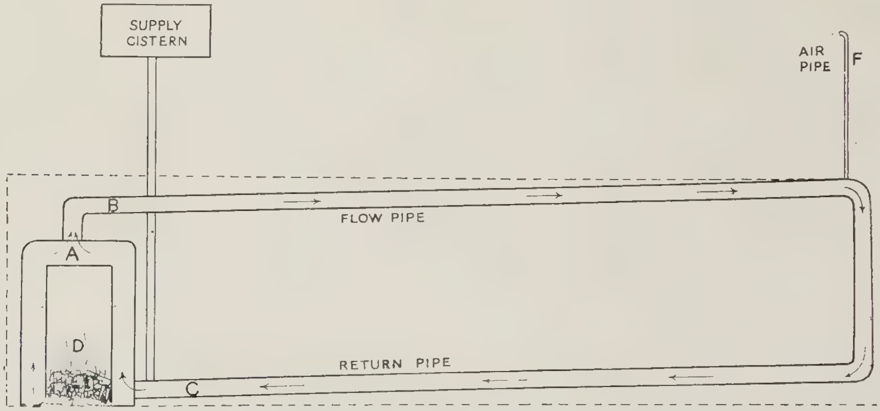


Fig. 179.—Diagram showing the Circulation of Hot Water in Greenhouse Pipes

boiler is constantly rising in temperature, and rushes to occupy the space that is being constantly vacated by the colder water.

If by any chance the water in the flow pipes and in the return pipes and boiler was of the same temperature, circulation would cease altogether, as when the fire goes out and the water cools. There must therefore be a difference in the balance between the hot and cold water to maintain a regular circulation. In other words, one column of water must be heavier than the other. This is secured by having the flow and return pipes at different heights, and the boiler at a lower level than either. When pipes are being set there is always a very slight rise in the flow pipe from the boiler to the end of the house, and a corresponding fall in the return pipe to the boiler. In this way a difference is secured in the two columns of water. And this difference is accentuated by having water in the supply cistern, which is placed several feet higher than the highest point of the flow pipe and is connected with a pipe to the return pipe. This supply cistern should always be kept filled with water, and as there is a pressure of about ½ lb. to every square inch of its surface for every foot in height, it will be realized at

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 FORCED LILAC PLANTS GROWN IN POTS FOR EXHIBITION

once what force is being exerted to drive the cold water into the boiler at the base, and the warm water out at the top.

Thus, if a supply cistern is 10 ft. above the base of the boiler, there will be 5 lb. pressure to every square inch; and at a height of 30 ft. the pressure would be 15 lb. on every square inch. Care must be taken not to cause too great a strain on the boiler and pipes by having the supply cistern too high. So long as the cistern is placed a foot or two above the highest point of the pipes, a good circulation will be secured with a minimum strain on the apparatus.

To show the enormous strain upon a boiler according to the height of the supply cistern the following remarks from Mr. W. Jones's work on *Heating by Hot Water* may be quoted: "Take a plain saddle boiler with 3-in. water space, and measuring 60 in. long by 21 in. wide by 21 in. high inside arch, the area or surface of which would be 7368 sq. in. Suppose the head of water to be 30 ft. above the centre of the boiler, $7368 \times 13{\cdot}02$ will give 95,931 lb., or nearly 43 tons *pressure* inside the boiler, whereas the actual *weight* of water in the boiler would not exceed 3 cwt. If you increase the head of water to a height of 60 ft. the *pressure* will be about 86 tons. If you lower it to 15 ft. it will be about 21½ tons, although the weight of water may remain the same in each case."

The system of hot-water heating for glasshouses is known as the "low-pressure" system, to distinguish it from the high-pressure system by which water is brought to boiling-point. Good growers never like their pipes to get so hot that they cannot bear the hand on them. When this is the case it indicates either bad and wasteful stoking or that the boiler is too powerful for the quantity of piping attached. Great heat in the pipes is injurious to plant life. It makes the atmosphere too dry, and when water is applied the house is filled with steam from the hot pipes for a time. A genial heat in the pipes is therefore most desirable.

It sometimes happens, however, more especially in very cold weather, that the fires must be "driven" to maintain the requisite temperature. Then the water is heated so much that it flows over from the supply cistern by sheer expansion. When the water cools it naturally takes up less space than before, the supply cistern becomes empty, and air enters the pipes to fill the vacuum caused by the lost water. The air must be got out of the pipes, otherwise the water could not enter in again. This is secured by means of an air pipe F, fixed at the highest point of the flow, and in many cases carried outside the house. Sometimes stopcocks are placed at the top of the flow pipes, and are examined regularly to allow the air to escape. In any case these air pipes are necessary, because, owing to the natural leakage of water by evaporation, air enters the pipes. If not expelled or allowed to escape, not only would the circulation of the water be impeded or stopped, but with great pressure the pipes or even the boiler might burst.

Quantity of Piping Required.—The following table, taken from Hood's work on hot-water heating, may be given as showing the length

of 4-in. piping required to heat 1000 cub. ft. of air per minute from 45° to 90° F., the temperature of the pipes being 200° F.

Temperature of External Air.	Temperature at which the House is to be kept.									
	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
	Number of Feet of 4-in. Pipe.									
10°	126	150	174	200	229	259	292	328	367	409
20°	91	112	135	160	187	216	247	281	318	358
30°	54	75	97	120	145	173	202	234	269	307
32°	47	67	89	112	137	164	193	225	259	296
40°	18	37	58	80	104	129	157	187	220	255
50°	—	—	19	40	62	86	112	140	171	204

If a house containing 10,000 cub. ft. of air is to be kept at a temperature of 70° F., the external air being at 32° (freezing-point), the amount of piping required is found thus: Go down the column under 70° and find the figures opposite the given temperature of the external air, that is 32°. The figures 164 stand opposite this and beneath the 70°. Multiply 164 by 10, and the result 1640 represents the number of feet of 4-in piping according to Hood's method. This, however, will scarcely do for horticultural purposes, as no one would dream of heating his hot-water pipes up to 200° F.—only twelve degrees below boiling-point. And, moreover, the length of piping cannot be varied at will, in accordance with the fluctuations of the external air. The quantity of piping is really regulated according to whether a structure is to be treated as a greenhouse or a hothouse, the latter requiring about twice as much piping as the former. Taking a house 100 ft. long, 12 ft. wide, and 8 ft. high to the ridge board with walls to the eaves 3 ft. high, we get a house with about 9000 ft. cubic capacity. If used as a greenhouse with a minimum winter temperature of 45° F., about 500 ft. of 4-in. piping will be sufficient in the usual way, but an extra 200 ft., making 700 ft. altogether, would maintain a temperature at a minimum of 50° to 55°. In a similar house, 1000 to 1200 ft. of 4-in. piping would maintain a stove temperature during the winter months without heating the pipes to more than 100° F.

Heating horticultural structures by steam is practised in America, where climatic conditions are different, but it is not likely to be adopted in Britain.

Fuel.—This is one of the greatest expenses to the commercial grower with extensive ranges of glass, and prices of coal and coke have increased enormously during the past twenty years, while the price of produce has fallen just as much; and labour has also increased. The two principal fuels used are coke and anthracite coal—some growers preferring one, some another. The prices vary according to circumstances, depending upon proximity or the reverse to supplies, freight charges, carriage, &c. The average price for coal and coke may be given as 20s. per ton, and a house

of 9000 ft. capacity, as mentioned above, will require from $\frac{1}{4}$ to $\frac{1}{2}$ ton per week if kept cool, or about 1 ton if treated as a stove. In the near future, perhaps, when science will have shown us how to make petroleum into a solid commercial article for heating purposes, there may be good times yet in store for the grower under glass. In the meantime he must pay the price asked for coal and coke, and see that he engages intelligent stokers to attend to his fires. A good stoker at 30*s*. per week is better than two bad stokers at 20*s*. each per week. [J. W.]

KEY TO THE MODEL OF A POTATO PLANT

Section I.—General View

Number references as for Section V below

Section II.—Epidermis of the Plant

1. Flower.
2. Fruit.
3. Diseased Leaf.
4. Healthy Leaf.
   (*a*) Midrib. (*b*) Vein.
5. Stem.
6. Healthy Tuber.
7. Diseased Tuber.

8, 9, Roots.

Section III.—Assimilation

Number references as for Section II above

(*a*) Denotes Inorganic Materials. (*b*) Denotes Organic Materials.

Section IV.—The Flow of Sap

Number references as for Section II above

(*a*) Denotes Inorganic Sap. (*b*) Denotes Organic Sap.

Section V

1. Flower (reduced).
2. Flower (natural size).
3. Calyx.
4. Corolla.
5. Stamens.
6. Style with Stigma.
7. Ovary.
8. Pollen Passage.
9. Petals.
10. Fruit (reduced).
11. Fruit (natural size).
12. Seeds.
13. Stem.
14. Roots.
15. Healthy Leaf (Upper Surface).
16. Epidermis of Leaf.
17. Palisade Cells with Chlorophyll Granules (very highly magnified).
18. Leaf Vein with Sieve Tubes (very highly magnified).
19. Spongy Parenchyma (very highly magnified).
20. Stomata.
21. Diseased Leaf (Upper Surface).
22. Epidermis destroyed by Fungi (very highly magnified).

23, 24, Palisade Cells and Spongy Parenchyma destroyed by Fungi (very highly magnified).

25. Stomata.
26. The Potato Disease (Section of the Leaf).
27. Healthy Tuber.
28. Eyes.
29. Skin.
30. Starch Grains coloured blue by Iodine (very highly magnified).
31. Section with Cellulose Threads.
32. Back View of Healthy Tuber.
33. Diseased Tuber with Fungus Growths.
34. Destruction of Skin by Fungi.
35. Destruction of Starch Grains by Fungi.
36. Destruction of Cellulose Threads by Fungi.
37. Back View of Diseased Tuber.

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